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ABSTRACT

These hearings focused on the reauthorization of appropriations for the National Science Foundation (NSF) for fiscal year (FY) 1985. (The Reagan administration's request for the NSF was $1.5 billion an increase of 13.6 percent over the FY 1984 budget.) The hearings include a prepared statement from Edward Knapp (NSF director) which provides an overview of the FY 1985 budget request and highlights of three initiatives proposed in FY 1985; these initiatives are: (1) the beginning of the construction of the Very Long Baseline Array, (2) expansion of support of computer networking and research time on supercomputers, and (3) a new program to establish cross-disciplinary research centers in engineering; plans for pre-college science and engineering education conclude this statement. Also included are statements and/or testimony from four NSF-funded research scientists--Jaime (Jim) Diaz (psychology), John Knauss (oceanography), Laurence Strong (chemistry), and Richard Claus (engineering), and also from: Anna Harrison (representing the American Association for the Advancement of Science); Robert Blastad Miller (executive director, Consortium of Social Science Associations); Warren Niederhauser (president, American Chemical Society); Robert Williams, Harlyn Halvorson, and Moselio Schaechter (representing the American Society for Microbiology); Strom Thurmond (senator, South Carolina) and Dan Quayle (senator, Indiana). (JN)

S. HRG. 98-1152

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION, 1985

HEARING

BEFORE THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON

EXAMINING THE REAUTHORIZATION OF APPROPRIATIONS FOR THE NATIONAL SCIENCE FOUNDATION FOR FISCAL YEAR 1985

APRIL 4, 1984

Printed for the use of the Committee on Labor and Human Resources

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WEDNESDAY, APRIL 4, 1984

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION, 1985

WEDNESDAY, APRIL 4, 1984

U.S. SENATE,
COMMITTEE ON LABOR AND HUMAN RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:10 a.m., in room SD-430, Dirksen Senate Office Building, Senator Orrin Hatch (chairman of the committee) presiding.

Present: Senators Hatch, Quayle, and Pell.

OPENING STATEMENT OF SENATOR HATCH

The CHAIRMAN. I am pleased to welcome everyone to this hearing, examining the National Science Foundation and its research achievements. It is NSF's mission to support the most promising basic and applied research in all scientific disciplines. The success of this mission is critical to the overall best interests of America's long-term economic growth, protection of our international competitive position, our national security, and the prospects for genuine and lasting peace.

We can all appreciate the advances that have been made in medicine, space science, and consumer technologies. Less apparent are the dedicated efforts of basic researchers to discover the new, fundamental knowledge which makes possible these well-publicized breakthroughs.

The distinguished scientists we have with us this morning are pioneers in this national search for scientific information, and on behalf of the committee I want to thank them for their willingness to share their research with us this morning.

The administration's budget request for the National Science Foundation is $1.5 billion. This is an increase of 13.6 percent over the fiscal year 1984 budget. I am delighted, though not surprised, by President Reagan's commitment to our shared belief in the potential of American science and engineering. Specifically, I am pleased to confirm the administration's support for increases in the target expenditures for instrumentation and equipment, science and engineering education, engineering research, and advanced scientific computing.

We expect to learn from our witness' presentations this morning how all of these new technologies are developed by the creativity and perseverance of our Nation's scientists and engineers in the pursuit of quality research. I am pleased to welcome these distinguished researchers to our hearing this morning. The projects you are going to discuss with us, of course, represent highlights of the research supported by the National Science Foundation, and I am looking forward to these presentations outlining the specific research NSF has funded with the appropriations authorized by this committee.

We are happy to have all of you here this morning. Let us introduce you. We have four NSF-supported research scientists. Our first will be Dr. Jim Diaz of the Department of Psychology at the University of Washington, in Seattle, WA, on developmental psychology, brain growth research, funded by the minority research initiation program. Second, we will call on Dr. John Knauss, who is dean of the Graduate School of Ocean Sciences at the University of Rhode Island, Narragansett, RI. He will discuss oceanography and the R/V *Endeavor*, supported by the Ocean Sciences Program. Third, we will hear from Dr. Laurence Strong, who is from the Department of Chemistry at Earlham College in Richmond, IN. He will talk about chemical instrumentation which is funded by the support for predominantly undergraduate institutions program. Finally, Dr. Richard O. Claus, who is with the College of Engineering at the Virginia Polytechnic and State University, in Blacksburg, VA. He will be discussing engineering, fiber optics in particular, which is funded by the Electrical, Computer, and Systems Engineering Program.

We will start with you, Dr. Diaz, and go from there. Thank you for being with us. But first, we will insert for the record a statement by Dr. Edward A. Knapp, Director, National Science Foundation.

[The prepared statement of Dr. Knapp follows:]

STATEMENT OF DR. EDWARD A. KNAPP, DIRECTOR, NATIONAL SCIENCE FOUNDATION

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I APPRECIATE THE OPPORTUNITY TO SUBMIT A STATEMENT FOR THE RECORD ON THE ADMINISTRATION'S FY 1985 BUDGET REQUEST FOR THE NATIONAL SCIENCE FOUNDATION.

I WILL HIGHLIGHT THREE INITIATIVES WE ARE PROPOSING IN FY 1985: (1) THE BEGINNING OF CONSTRUCTION ON THE VERY LONG BASELINE ARRAY (VLBA); (2) AN EXPANSION OF SUPPORT OF COMPUTER NETWORKING AND RESEARCH TIME ON SUPERCOMPUTERS, AND (3) A NEW PROGRAM TO ESTABLISH CROSS-DISCIPLINARY RESEARCH CENTERS IN ENGINEERING. I WILL CONCLUDE WITH A BRIEF DISCUSSION OF OUR PLANS FOR PRE-COLLEGE SCIENCE AND ENGINEERING EDUCATION.

THE FY 1985 REQUEST: AN OVERVIEW

OUR BUDGET REQUEST FOR FY 1985 IS $1.5 BILLION, AN INCREASE OF 13.6 PERCENT ABOVE FY 1984. THIS TOTAL INCLUDES $1.3 BILLION FOR OUR RESEARCH AND RELATED ACTIVITIES; $76 MILLION FOR SCIENCE AND ENGINEERING EDUCATION; $115 MILLION FOR THE U.S. ANTARCTIC PROGRAM; AND $2.8 MILLION FOR FOREIGN CURRENCY.

THIS PROPOSED BUDGET REFLECTS THE ADMINISTRATION'S DEEP COMMITMENT TO EXCELLENCE IN OUR COUNTRY'S PURSUIT OF SCIENTIFIC AND TECHNOLOGICAL ACHIEVEMENTS AND IN THE TRAINING OF OUR FUTURE SCIENTISTS AND ENGINEERS. IT ALSO REFLECTS THE VERY STRONG

SUPPORT WHICH THE FOUNDATION'S PROGRAMS RECEIVED FROM THIS COMMITTEE AND THE CONGRESS LAST YEAR. THE PROGRAM THAT THIS PROPOSED BUDGET WILL SUPPORT IS STRONG AND WELL-BALANCED. IT PROVIDES FOR SOME VERY EXCITING BASIC RESEARCH, WITH EMPHASIS ON AREAS THAT CONTRIBUTE MOST TO OUR CONTINUED ECONOMIC WELL-BEING AND TECHNOLOGICAL CAPABILITIES. LET ME DESCRIBE SOME HIGHLIGHTS OF OUR PLANS FOR FY 1985.

- OVERALL EMPHASIS ON ENGINEERING AND THE PHYSICAL SCIENCES CONTINUES, WITH SPECIAL ATTENTION TO MATHEMATICS, COMPUTER RESEARCH, MECHANICAL, ELECTRICAL AND COMPUTER ENGINEERING, ASTRONOMY AND THE EARTH SCIENCES.

- WITHIN THE BIOLOGICAL SCIENCES, WE WILL CONTINUE TO GIVE PRIORITY TO RESEARCH ON PLANT BIOLOGY. WORK IN THIS SCIENTIFICALLY AND ECONOMICALLY IMPORTANT AREA WILL INCLUDE SUCH TOPICS AS THE COVERSION OF SOLAR ENERGY TO CHEMICAL ENERGY BY PLANTS; NITROGEN FIXATION; AND THE REGENERATION OF PLANTS FROM A SINGLE CELL.

- WE WILL INITIATE A NEW RESEARCH THRUST INVOLVING OUR PROGRAMS IN CHEMISTRY, AND THE BIOLOGICAL SCIENCES TO INVESTIGATE THE CHEMISTRY OF LIFE PROCESS. SUCH FUNDAMENTAL WORK IS ESSENTIAL FOR THE DEVELOPMENT OF BIOTECHNOLOGIES RELATED TO MEDICINE AND AGRICULTURE.

- Within the earth sciences, we will place an increased emphasis on studies of the continental lithosphere to provide a possible basis for future continental scientific drilling.

- We are requesting $27.6 million for our Ocean Drilling program in FY 1985, with additional foreign contributions of about $10.0 million. A lease for a large, modern drillship was recently signed with SEDCO, Inc., and we will begin modifications for scientific drilling later in the year. The first drilling leg is planned to start in January, 1985.

- We will increase support for research at predominantly undergraduate institutions by over 15 percent. These institutions provide undergraduate training for many of our Nation's future scientists and engineers.

- In the U.S. Antarctic Program, we will continue to restore or replace obsolete facilities, particularly at McMurdo Station. Major construction projects started in prior years will continue, and the salt water distillation plant should be complete and operating in FY 1985.

Our plans to institute a Service Life Extension Program for our LC-130 Aircraft were delayed by major contract negotiation problems between the Department of Defense

AND PRIVATE CONTRACTORS. WE ARE INVESTIGATING ALTERNATIVES FOR COMPLETING THE SERVICE LIFE EXTENSION ON THESE CRITICAL AIRCRAFT.

o WE WILL INCREASE SUPPORT OF INTERNATIONAL SCIENTIFIC ACTIVITIES IN THE FOUNDATION'S RESEARCH PROGRAMS AND WILL GIVE SPECIAL EMPHASIS TO MAINTENANCE OF PROGRAMS WITH CHINA, SUB-SAHARA, AFRICA, AND LATIN AMERICA.

o WE WILL INITIATE A NEW PROGRAM TO ASSIST WOMEN SCIENTISTS AND ENGINEERS, WHOSE CAREERS HAVE BEEN INTERRUPTED, TO RESUME THEIR RESEARCH ACTIVITIES AND ALSO PROVIDE RESEARCH INITIATION GRANTS TO WOMEN SCIENTISTS AND ENGINEERS.

o FOR THE FOURTH YEAR IN A ROW WE ARE PLACING A HIGH PRIORITY ON SCIENTIFIC RESEARCH INSTRUMENTATION. WE ESTIMATE THAT TOTAL SUPPORT OF INSTRUMENTATION AND FACILITIES WILL REACH $237.0 MILLION, AN INCREASE OF 20.3 PERCENT OVER FY 1984. THE DOLLARS WHICH NSF PUTS INTO INSTRUMENTS AND FACILITIES HAVE A VERY SIGNIFICANT "MULTIPLIER EFFECT," BENEFITING MANY MORE SCIENTISTS, ENGINEERS AND GRADUATE STUDENTS THAN JUST THOSE RECEIVING DIRECT SUPPORT THROUGH GRANTS.

- We will be supporting over 11,000 graduate students on NSF grants for a total of $103 million. This is an increase of 16 percent over FY 1984. There will be 550 new NSF graduate fellowships next year for a total of approximately 1,550. We will increase the annual stipend from $8,100 to $9,000.

- We will support an additional 200 young scientists and engineers through the Presidential Young Investigator Awards program, bringing the total to 400 in FY 1985. With matching funds from industry, these awards will encourage promising young people to remain in academic careers to train future generations of scientists and engineers.

In these and other ways NSF activities contribute directly to the quality of education in our colleges and universities. Indeed, I believe that virtually our entire budget has a significant impact on the quality of science and engineering education in this country!

- Only 4.7 percent of our Request, a total of $70.9 million, will be required to support our staff, central support services, management information systems (MIS), travel and use of consultants in FY 1985. Our full-time equivalent employment, which has declined by 8 percent since FY 1982, will remain at 1,194 in FY 1984. With the

REORGANIZATION WHICH I ANNOUNCED IN OCTOBER, 1983, I EXPECT TO INCREASE OUR STAFFING IN SCIENCE AND ENGINEERING EDUCATION AND MEET THE EXPANDED RESPONSIBILITIES GIVEN TO US BY THE CONGRESS. WE ARE REQUESTING A 16 PERCENT INCREASE IN STAFF AND CONSULTANT TRAVEL PRIMARILY TO SUPPORT OUR EXPANDED PROGRAMMATIC RESPONSIBILITIES IN EDUCATION AND OUR PROPOSED INITIATIVES. OUR TRAVEL LIMITATION HAS REMAINED LEVEL FOR THE PAST TWO YEARS.

FINALLY, THE REQUESTED INCREASE FOR DATA PROCESSING EQUIPMENT IN FY 1985 IS LARGELY OFFSET BY ECONOMIES WE HAVE REALIZED ELSEWHERE, SO THAT THE TOTAL COST OF OUR MIS IS ONLY SLIGHTLY MORE THAN IT WAS IN FY 1982. BY THE END OF FY 1985, WE WILL HAVE COMPLETED OUR TRANSITION TO A NEW DATA PROCESSING ENVIRONMENT. THIS WILL SUBSTANTIALLY INCREASE THE EFFICIENCY AND EFFECTIVENESS OF OUR STAFF.

VERY LONG BASELINE ARRAY (VLBA)

ONE OF THE HIGHLIGHTS OF OUR FY 1985 BUDGET REQUEST IS OUR PROPOSAL TO BEGIN CONSTRUCTION OF THE VERY LONG BASELINE ARRAY, FOR WHICH WE ARE REQUESTING $15.0 MILLION.

This radio telescope is the top priority instrument for ground-based astronomy recommended by the National Academy of Sciences/National Research Council Astronomical Survey Committee in January, 1982. Earlier technical studies outlined the scientific need and conceptual design for such an instrument. As you know, our FY 1984 budget includes $2.5 million for antenna and instrument design and site selection studies which are being done by the National Radio Astronomy Observatory (NRAO). These design and site studies will provide the basis for the construction to begin in a timely fashion in FY 1985.

Our Project Development Plan was submitted to the National Science Board in February, 1983, and with their endorsement it provides the basis for our FY 1985 request. The total construction costs, in FY 1985 dollars, are estimated at $64.0 million. Operation of part of the array could begin as early as FY 1987 at an operating cost of about $2.0 million per year with full array operation possible by FY 1988 at about $5.0 million per year.

Advanced Scientific Computing

Let me now turn to a different but equally challenging area of science: Advanced Scientific Computing.

Last May, participants in an NSF Workshop representing a wide spectrum of disciplines from academia, industry, and government

RESEARCH LABS. WERE ASKED TO CONSIDER POTENTIAL REQUIREMENTS IN FOUR AREAS:

- LARGE-SCALE CAPACITY;
- NEW COMPUTING CAPABILITY;
- LOCAL FACILITIES; AND
- NETWORKS.

THERE WAS VIRTUALLY UNANIMOUS AGREEMENT THAT IMPORTANT SCIENCE IS NOT BEING DONE BECAUSE ACADEMIC SCIENTISTS AND ENGINEERS HAVE LIMITED ACCESS TO COMPUTATIONAL RESOURCES. WORKSHOP PARTICIPANTS ALSO RECOGNIZED A KIND OF "CHICKEN AND EGG" PROBLEM: THE NEEDS FOR ACCESS TO SUPERCOMPUTERS IN A VARIETY OF DISCIPLINES ARE NOT WELL SPECIFIED OR UNDERSTOOD, YET IT IS LIKELY THAT THEY WILL NEVER BE IDENTIFIED FULLY UNTIL SCIENTISTS HAVE MUCH BETTER ACCESS THAN AT PRESENT.

IN MANY CASES THE ACADEMIC SCIENTIFIC AND ENGINEERING COMMUNITY WILL BE LEARNING AND EXPLORING DURING THE EARLY STAGES OF ANY SUPERCOMPUTER PROGRAM, INVENTING NEW IDEAS AND REDEFINING OLD ONES AS THEY INTERACT WITH EACH OTHER AND AS THEY USE AND DEVELOP SUPERCOMPUTER SOFTWARE AND HARDWARE. AS THIS LEARNING AND EXPLORING PROCEEDS, THE NEED FOR LARGE-SCALE COMPUTING CAPACITY IN UNIVERSITIES WILL GROW SUBSTANTIALLY. GIVEN THE RATE

AT WHICH SUCH TECHNOLOGY IMPROVES AND CHANGES, OPENING UP STILL NEW OPPORTUNITIES FOR EXPLORATION, WE MAY NEVER CATCH UP. IN FACT, IF WE ARE DOING THINGS RIGHT, WE SHOULD NEVER CATCH UP WITH THE NEED!

WORKSHOP PARTICIPANTS ALSO AGREED THAT LOCAL FACILITIES MUST BE SIGNIFICANTLY ENHANCED FOR A BALANCED RESPONSE TO THESE NEW COMPUTATIONAL OPPORTUNITIES. SUPERCOMPUTER ACCESS SHOULD BE MANAGED AS A SCARCE RESOURCE, AND ANY CALCULATION NOT REQUIRING THIS ADVANCED CAPABILITY SHOULD BE PERFORMED ON SMALLER COMPUTERS. MOST SCIENTIFIC CALCULATIONS WILL NOT REQUIRE SUPERCOMPUTERS.

FINALLY, WORKSHOP PARTICIPANTS AGREED THAT SUBSTANTIALLY ENHANCED SCIENTIFIC NETWORKS LINKING MANY DIVERSE RESEARCH COMMUNITIES TO EACH OTHER AND TO COMPUTATIONAL FACILITIES ARE EXTREMELY IMPORTANT. FOR ONE THING, AN EFFECTIVE COMMUNICATIONS NETWORK WILL ENCOURAGE THE BROAD SHARING OF IDEAS AND EXPERIENCES AMONG RESEARCHERS AND HELP OVERCOME SOME OF THE FRAGMENTATION WHICH PRESENTLY EXISTS. ITS DEVELOPMENT, IN CONJUNCTION WITH THE GROWTH OF SUPERCOMPUTER CAPABILITY, WILL PUSH THE STATE-OF-THE-ART IN SOFTWARE, NETWORK DESIGN, EQUIPMENT, AND NETWORK MANAGEMENT AND GIVE RISE TO NEW, UNEXPECTED DISCOVERIES. THESE DISCOVERIES WILL BE USED TO DESIGN FUTURE COMPUTATIONAL SYSTEMS WELL BEYOND OUR CAPABILITIES TODAY. COMPUTER NETWORKS, PROPERLY DESIGNED AND MANAGED, WILL BRING ABOUT EFFICIENT, REMOTE ACCESS TO THESE SCARCE COMPUTATIONAL RESOURCES. THESE THREE THINGS WILL SUBSTANTIALLY ENHANCE THE FOUNDATION'S INVESTMENT.

IN FY 1984, OUR FIRST ORDER OF BUSINESS IS TO ARRANGE FOR LARGE BLOCKS OF TIME AT EXISTING COMPUTATIONAL SITES FOR NSF GRANTEES WHOSE RESEARCH WILL BENEFIT FROM SUCH ACCESS. WE HAVE SET ASIDE UP TO $6.0 MILLION FOR THIS PURPOSE SO THAT COMPUTER SERVICE CAN BE MADE AVAILABLE TO SCIENTISTS AND ENGINEERS IN ALL THE DISCIPLINES REPRESENTED IN THE NSF.

IN THE FALL OF 1983, THE FOUNDATION ISSUED A SOLICITATION INVITING PROPOSALS WHICH OFFERED BLOCKS OF TIME FOR USE BY NSF RESEARCHERS. SEVEN COMPETITIVE PROPOSALS WERE RECEIVED AND HAVE BEEN REVIEWED BY THE NSF STAFF AND THE NEW ADVISORY COMMITTEE AT ITS FIRST MEETING. WE EXPECT TO MAKE A DECISION SOMETIME LATER THIS SPRING. THE PLAN IS TO ARRANGE FOR UP TO THE EQUIVALENT OF ONE SUPERCOMPUTER FOR USE BY RESEARCHERS.

WE ARE REQUESTING $20.0 MILLION FOR THE TOTAL PROGRAM IN FY 1985. WHILE OUR PLANS ARE STILL EVOLVING, WE ANTICIPATE USING UP TO HALF OF THIS AMOUNT FOR SUPERCOMPUTER ACCESS BY RESEACHERS.

WE PLAN TO INITIATE AN ADDITIONAL PHASE OF OUR LONG-RANGE PROGRAM BY THE END OF FY 1984 WITH THE SELECTION OF A SCIENTIFIC AND TECHNICAL ORGANIZATION TO MANAGE THE DESIGN, DEVELOPMENT, AND EVENTUAL IMPLEMENTATION OF A NEW <u>COMPUTATIONAL NETWORK</u>. THIS <u>NETWORK</u> WILL EFFICIENTLY LINK RESEARCHERS WITH EACH OTHER AND WITH EXISTING AND NEW SUPERCOMPUTER CENTERS AND THEIR TRAINER STAFFS. UNTIL THIS <u>NETWORK</u> IS COMPLETE, OR AT LEAST FAIRLY FAR

ALONG, REMOTE ACCESS WILL BE LIMITED TO RELATIVELY SLOW TELEPHONE LINES, AND MANY INVESTIGATORS WILL HAVE TO BE ON SITE IN ORDER TO CONDUCT THEIR RESEARCH. WE WILL PROVIDE SUPPORT FOR THE INITIAL STAGES OF THIS NETWORK, ABOUT $5.0 MILLION, FROM OUR FY 1985 REQUEST.

- ANOTHER $5.0 MILLION WILL BE USED TO PROVIDE LOCAL EQUIPMENT NEEDED TO ACCESS THE COMPUTATIONAL NETWORK AND TO SUPPORT EXPERIMENTS WITH BROAD-BAND COMMUNICATIONS.

DEPENDING ON THE FINAL COST OF THE BLOCKS OF TIME WHICH WE PURCHASE IN FY 1984 AND FY 1985, WE MAY HAVE SUFFICIENT RESOURCES WITHIN OUR REQUEST TO CONSIDER THE INITIAL PHASE OF SUPPORT FOR A NEW SUPERCOMPUTER USER FACILITY, EITHER BY ADDING ON TO AN EXISTING FACILITY OR BEGINNING A NEW CENTER. I SHALL KEEP THIS COMMITTEE FULLY INFORMED AS OUR PLANS IN THIS REGARD DEVELOP.

CROSS-DISCIPLINARY RESEARCH CENTERS IN ENGINEERING

THERE IS A THIRD EXCITING AND NATIONALLY IMPORTANT AREA IN OUR REQUEST WHICH I WOULD NOW LIKE TO ADDRESS: RESEARCH AND EDUCATION IN ENGINEERING AND OUR PLANS FOR A NEW PROGRAM FOR CROSS-DISCIPLINARY ENGINEERING RESEARCH CENTERS IN FY 1985. WE ARE PROPOSING $10.0 MILLION FOR THIS PURPOSE AND EXPECT TO FUND UP TO FIVE CENTERS IN THE FIRST YEAR.

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THE PROPOSAL HAS BEEN SHAPED BY THE FOUNDATION'S GENERAL RESPONSIBILITIES FOR THE HEALTH OF BASIC SCIENCE AND ENGINEERING IN THE UNITED STATES. MORE SPECIFIC GUIDANCE FROM THE NATIONAL SCIENCE BOARD AND THE NATIONAL ACADEMY OF ENGINEERING LED US TO SEEK WAYS TO STRENGTHEN THE ENGINEERING EDUCATION AND RESEARCH CAPABILITIES OF OUR UNIVERSITIES AND COLLEGES.

WHILE THE SPECIFIC DETAILS OF THIS NEW PROGRAM ARE STILL BEING WORKED OUT, THE CENTERS WILL:

- FOCUS ON MAJOR TECHNOLOGICAL CONCERNS OF BOTH INDUSTRIAL AND NATIONAL IMPORTANCE IN ORDER TO DEVELOP FUNDAMENTAL KNOWLEDGE IN AREAS CRITICAL TO U.S. COMPETITIVENESS IN WORLD MARKETS.

- BRING TOGETHER ENGINEERS AND SCIENTISTS WITH DIFFERENT SKILLS AND BACKGROUNDS TO FACILITATE THE KINDS OF "CROSS-DISCIPLINARY" INTERACTIONS AND RESEARCH WHICH PARALLEL THE WORKING WORLD OF INDUSTRY AND WHICH ARE NEEDED TO SOLVE THE LONG-TERM TECHNICAL CHALLENGES UNDERLYING EMERGING AREAS OF TECHNOLOGY.

- PROVIDE THE EXPENSIVE, STABLE EXPERIMENTAL CAPABILITIES, INCLUDING INSTRUMENTATION, SKILLED TECHNICIANS, AND MANAGEMENT NOT AVAILABLE TO INDIVIDUAL INVESTIGATORS WORKING ON SMALLER STAND-ALONE PROJECTS.

- Include participation by industrial scientists and engineers to make certain that activities focus on long-term industrial needs and provide an industrial "window" for faculty and students to improve their understanding of the practice of engineering.

- Involve both graduate and undergraduate engineering students in research activities, giving them hands-on experience with research and training them to operate more effectively in the "cross-disciplinary" world of engineering practice.

We are very excited by the prospect that these Centers will contribute significantly to the substance and quality of engineering research and education.

PRE-COLLEGE SCIENCE EDUCATION

Let me now turn to the final topic: pre-college science education.

There has been a national ground swell of concern in the last few years about the quality of pre-college science and mathematics education in our Nation's primary and secondary schools. Editorials across the country have decried the state of affairs, attributing it to a variety of causes. School boards,

TEACHERS ASSOCIATIONS, PARENTS GROUPS, SCIENTIFIC AND PROFESSIONAL SOCIETIES, AND OTHERS IN STATE AFTER STATE ARE DISCUSSING THE PROBLEM AND PROPOSING REMEDIES.

WE HAVE BEEN WORKING VERY CLOSELY WITH THE CONGRESS SINCE LAST SPRING TO IMPLEMENT A NEW PROGRAM IN PRE-COLLEGE SCIENCE AND MATHEMATICS EDUCATION WHICH IS RESPONSIVE TO THESE CHALLENGES. IN THIS, WE HAVE BEEN GUIDED BY THE RECOMMENDATIONS OF THE NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY. THEIR REPORT IDENTIFIED THREE KINDS OF TALENT REQUIRED AMONG OUR CITIZENS:

o PROFESSIONAL SCIENTISTS, ENGINEERS, AND TECHNICIANS ---THE CENTERPIECE OF OUR TECHNOLOGICAL SOCIETY.

o THE INVESTORS, BUSINESSMEN, LEGISLATORS, AND DECISION MAKERS WHO MUST HAVE AN UNDERSTANDING OF SCIENCE AND TECHNOLOGY TO CARRY OUT THEIR DAY-TO-DAY WORK; AND

o A SCIENTIFICALLY AWARE AND UNDERSTANDING CITIZENRY.

OUR EDUCATIONAL SYSTEM MUST SERVE STUDENTS WITH IMMENSELY VARIED ABILITIES AND CULTURAL BACKGROUNDS.

THE PROBLEM IS: HOW CAN THE NSF PROVIDE THE BASIS FOR HIGH QUALITY SCIENCE AND MATHEMATICS PRE-COLLEGE EDUCATION THAT SERVES THIS FULL SPECTRUM OF STUDENTS? WE TRADITIONALLY -- AND

APPROPRIATELY -- HAVE BEEN CONCERNED WITH THE SUPPLY OF MATHEMATICIANS, SCIENTISTS, AND ENGINEERS. OUR GRADUATE PROGRAMS, OUR SUPPORT OF RESEARCH, OUR DEVELOPMENT OF MODEL PRE-COLLEGE CURRICULA IN THE MAJOR DISCIPLINES, AND OUR EFFORTS TO UPGRADE THE SKILLS OF SCIENCE TEACHERS HAVE ALL BEEN DIRECTED TOWARD THIS OBJECTIVE.

BUT NOW THE COUNTRY CHALLENGES US WITH A MUCH MORE DIFFICULT PROBLEM: THE QUALITY OF GENERAL EDUCATION FOR ALL STUDENTS. WE WELCOME THAT CHALLENGE; WE BELIEVE THAT NSF CAN PLAY A SIGNIFICANT ROLE.

AT THE SAME TIME, WE ARE KEENLY AWARE OF THE PLURALISTIC NATURE OF OUR SYSTEM. THERE ARE IMPORTANT AND APPROPRIATE LIMITATIONS -- BOTH FOR GOVERNMENT IN GENERAL AND THE NATIONAL SCIENCE FOUNDATION IN PARTICULAR. NSF'S PRINCIPAL STRENGTHS ARE ITS CLOSE TIES WITH ACADEMIC INSTITUTIONS, ITS EXPERIENCE IN SUPPORTING RESEARCH, AND ITS TRADITION OF PEER REVIEW TO ENSURE EXCELLENCE. IT IS NOT OUR PLACE TO PARTICIPATE MASSIVELY IN THE PRE-COLLEGE EDUCATIONAL ENTERPRISE. RATHER, OUR BEST ROLE IS AS A CATALYST, ENCOURAGING AND SUPPORTING THE PARTICIPATION OF SUCH DIVERSE GROUPS AS SCIENTIFIC SOCIETIES, EDUCATIONAL PUBLISHERS, EDUCATIONAL DEVELOPERS, AND SCHOOL SYSTEMS.

WITH THESE IDEAS IN MIND, OUR INITIAL PROGRAM HAS TWO MAJOR ELEMENTS:

1. PROGRAMS TO INCREASE THE KNOWLEDGE AND SKILLS OF PRACTICING TEACHERS AND TO ENHANCE THE PRESTIGE OF THE PROFESSION; TO DEVELOP MATERIALS AND TEACHING AIDS TO MAKE SCIENTIFIC CONCEPTS CLEAR TO ALL STUDENTS; TO DEMONSTRATE NEW METHODS THAT CAN IMPROVE THE TEACHING ENVIRONMENT; AND TO INTEGRATE NEW TECHNOLOGY INTO TEACHING.

2. PROGRAMS TO BETTER UNDERSTAND SCIENCE EDUCATION PROBLEMS; ASSESS THE SUCCESS OF EXISTING AND NEW TOOLS AND METHODOLOGIES; AND PURSUE APPROACHES THAT OFFER PROMISE OF IMPROVEMENT IN SCIENCE EDUCATION OUTSIDE THE CLASSROOM.

A HYBRID MANAGEMENT STYLE IS REQUIRED TO CARRY OUT THESE TASKS. WE MUST HAVE A SYSTEM THAT IS OPEN TO ANY PROPOSAL OF MERIT, YET AT THE SAME TIME CAN FOCUS EFFORTS IN A PLANNED WAY SO THAT WE PROCEED FROM PROBLEM DEFINITIONS TO DESIGN, TO MAJOR DEVELOPMENT, AND FINALLY TO ACTIVE APPLICATION IN AN APPRECIABLE NUMBER OF CLASSROOMS.

WE ARE ENCOURAGING THE CONVENING OF PLANNING WORKSHOPS BY A VARIETY OF SCIENTIFIC, PROFESSIONAL, AND EDUCATIONAL ASSOCIATIONS TO HELP DEVELOP CONSENSUS ON NEEDS AND TO FOCUS BETTER THE PROPOSALS THAT ARE SUBMITTED TO US. WE WILL THEN USE AN ACTIVE PEER REVIEW PROCESS -- BROADENED TO INCLUDE ALL OF THE

SCIENTIFIC, EDUCATIONAL, ECONOMIC, TECHNICAL, AND INSTITUTIONAL KNOWLEDGE REQUIRED FOR JUDGEMENTS OF EDUCATIONAL EXCELLENCE AND UTILITY -- TO SELECT THE BEST OF THESE. WE ARE PRESENTLY DESIGNING AN ORGANIZATIONAL AND PLANNING STYLE APPROPRIATE TO THESE MANAGEMENT CHALLENGES, AND I EXPECT TO BE REPORTING ON OUR PROGRESS TO THIS COMMITTEE SOON.

THE SCIENCE AND ENGINEERING EDUCATION DIRECTORATE WAS RE-ESTABLISHED ON OCTOBER 1, 1983, AND WE ARE WORKING TO STAFF IT WITH EXPERTS IN APPROPRIATE FIELDS. AN ADVISORY COMMITTEE WILL SOON BE APPOINTED TO PROVIDE US WITH EXPERT VIEWS ON OUR PROGRAMS AS THEY EVOLVE. NEARLY ALL 1983 APPROPRIATED FUNDS HAVE BEEN OBLIGATED, MOSTLY TO TEACHING MATERIALS DEVELOPMENT AND HONORS TEACHER WORKSHOPS, AND WE ARE WORKING HARD TO EVALUATE THE PROPOSALS RECEIVED IN FY 1984.

WE ARE REQUESTING A TOTAL OF $54.7 MILLION FOR PRE-COLLEGE SCIENCE AND MATHEMATICS AGAIN IN FY 1985. I FIRMLY BELIEVE THAT AT THIS LEVEL WE WILL BE ABLE TO BUILD UP THE KIND OF HIGH QUALITY SCIENCE EDUCATION PROGRAM THAT IS MORE FOCUSED, MORE STABLE, AND MORE CONSISTENT THAN THOSE WE HAVE HAD IN THE PAST, A PROGRAM THAT DRAWS ON THE BEST THAT THE NSF HAS TO OFFER, ALLOWING IT TO PLAY ITS PROPER EDUCATIONAL ROLE OF <u>CATALYST</u> AND <u>SUPPORTER</u>.

CONCLUSION

WE BELIEVE THAT THE ADMINISTRATION HAS SUBMITTED A WELL-BALANCED BUDGET REQUEST FOR FY 1985 FOR THE NSF. IT PROPOSES SIGNIFICANT INCREASES IN THOSE FIELDS OF RESEARCH ---CHEMISTRY, PHYSICS, MATERIALS, COMPUTER SCIENCE, ENGINEERING, PLANT BIOLOGY, GEOSCIENCE, MATHEMATICS --- WHICH ARE IMPORTANT TO OUR ECONOMIC COMPETITIVENESS AND NATIONAL SECURITY. I HAVE EMPHASIZED THREE OF OUR MOST EXCITING INITIATIVES AS WELL AS OUR EFFORTS TO DESIGN AN EFFECTIVE PROGRAM IN PRE-COLLEGE SCIENCE AND MATHEMATICS EDUCATION.

WE SUPPORT MANY SCIENTISTS AND ENGINEERS, DIRECTLY AND INDIRECTLY, ACROSS THE NATION. ALL OF OUR ACTIVITIES HAVE A STRONG EDUCATIONAL INFLUENCE ON OUR COLLEGES AND UNIVERSITIES. THE NEARLY 14 PERCENT INCREASE WE ARE REQUESTING IN FY 1985 WILL STRENGTHEN THESE FEATURES OF OUR PROGRAMS, ESPECIALLY OUR EMPHASIS ON RESEARCH INSTRUMENTATION.

I URGE YOUR COMMITTEE TO SUPPORT THE ADMINISTRATION'S REQUEST.

STATEMENT OF JAIME (JIM) DIAZ, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF WASHINGTON, SEATTLE, WA

Dr. DIAZ. As a physiological psychologist, my science in general involves how the brain mediates behavior. More specifically, my research examines how the brain develops and especially how normal brain development can be disrupted by different factors, for instance drugs and undernutrition. Currently, my research is focusing on a particular phase of brain development, a period that is called a "brain growth spurt."

As the name implies, the brain growth-spurt is a time when the brain is growing at its absolutely fastest rate. The first slide shows velocity curves, just how fast the brain is growing, for a variety of species. I would like to draw your attention to the solid [illegible] line, which is the brain growth spurt for the human. For [illegible]an, the brain growth spurt begins around mid-pregnan[illegible] can extend well into the fourth post-natal year, and it peaks around the time of birth. The brain growth spurt happens in all mammals, and its timing relative to birth, as you can see, varies from species to species.

What exactly is happening during this time is that there is explosive growth. In particular, what you have is the establishment of some populations of cells, but more importantly what is happening during this period is that it is a time for the formation of connections between the neurons and the central nervous system. Quite literally, the brain is wiring itself up during this time. Cells are making point-to-point contact. Unfortunately, the period of fastest growth is also a period of maximum vulnerability, which is to say that during this complicated growth program, the growth of the brain at this time is most easily disrupted by a variety of different insults or traumas.

Now, when you think about it, the brain is the single most important organ, in terms of behavior. What we do and what we are is how the brain works. And so, that the wiring happens so quickly and that the wiring of this particular organ can be disrupted so easily is what I find particularly interesting as a psychologist and why I feel compelled to study this particular period of brain growth.

To study the particulars of the vulnerability during this time necessarily means that you are going to have to go to animal models. It makes it problematic. Notice that the brain growth spurt for the rat, which is the dotted line to the right, occurs primarily post-natally. It occurs after birth in the rat, whereas in the human it is occurring before and after the event of birth. So an important point from a family of curves like this is that the fetal rat is not the same as the fetal human. If you are going to model an important period of brain growth in an animal like the rat, you have to be aware of the fact that you have to compare stages of development, as opposed to the absolute age.

Once you have come to that kind of conceptual breakthrough, then a methodological problem immediately presents itself. If you are going to model the brain growth spurt in the rat, you will necessarily have to involve working with rat pups that are nursing. That is a major problem.

One of my strongest interests is the effect of drugs on brain development. Any drug, any trauma that you may induce during this nursing period, is going to interfere with nursing. If you find your results are promising, you do not know if those results are due to the actual drug or manipulation or if it is due to the fact that these animals are not nursing properly. So what you need is an animal that does not have to nurse, although an animal at this age cannot survive on its own.

To solve this dilemma, I have refined a surgical procedure in which I surgically install a feeding line directly to the rat pups. What I have is a rat that does not have to nurse. This is a 17-day-old rat pup, and you can see in the front, on the left side of the animal, there is a tube. These animals get fed directly, and they do not have to nurse. So I maintain these animals in these plastic cups, in warm water baths, and now I have a preparation that allows me to look at this particular period of time—more importantly, this particular period of brain growth—and not have to worry about an animal that is not nursing. All the animals are receiving the same amount of milk at the same time of day.

With this kind of a preparation, we are able to examine and model the brain growth spurt.

One of the drugs that is most commonly used in human neonates and infants are barbiturates, oddly enough. So we looked at phenobarbital, which is perhaps the most popular drug given to infants. We looked at that first. Recall now that the brain growth spurt can extend into the fourth postnatal year. We wanted to model what would happen if you exposed a developing brain to a drug as powerful as barbiturates during this time.

What we found was this: That, using this procedure, we were able to maintain body weights—body weights are on the left side—so our animals did not lose any weight, they were adequately nourished, but we found that phenobarbital, given at a time that mimics the early postnatal time in a human, and at doses that are clinically within the ballpark of what infants will see in a clinic, retards brain growth and retards brain growth significantly.

The importance of something like this is, if you pick up most pediatric neurology textbooks, phenobarbital is considered safe. It is a safe drug to give to infants. The reason it is safe is, infants do not die, but this kind of attitude does not address itself to the notion of a brain that is connecting, a period of brain growth that is essential for this person as they develop and for later life. So the position that I maintain, in terms of drugs that are prescribed, is that anything that will disrupt the brain growth spurt is a risk. Until now, there was no way of adequately trying to figure out just how much of a risk it is, and this kind of a procedure enables not only the studying of the brain and what is necessary for normal brain development but can help in assessing just how traumatic certain drug exposures may be.

The general feeling of the medical community right now is that once an infant or a developing individual passes the first trimester, they are out of the woods; it is safe. While it is true that the first trimester is a time for organs to form, including the brain, I find that this is to ignore the critical periods that occur later in gestation, say the third trimester and certainly postnatally. If the attitude is that after the first trimester, an infant is safe or a developing fetus is safe, certainly after the person is born, people have less of a concern about drug exposures and about traumatic exposures. I think that my data talk to a more cautious approach to it.

We decided, using this model, to look at the effects of alcohol at a time of brain growth that is similar to a third trimester. Again, the notion in this particular line of research was to explode the myth that once you pass the first trimester that a person is safe. We exposed animals for a very short period of time to alcohol, at levels that were not unlike the levels that are seen in clinics, certainly in the Seattle area, to women that were not cautious of their drinking during pregnancy. We found similar results, without any drop in body weight, for a substantial drop in brain weight.

You can see the data on the right for brain weights. If you look at the brains themselves, you can see it. Alcohol has a severely retarding effect on brain development. So with this model, we are able to develop an accurate model of fetal alcohol syndrome, as far as brain growth is concerned.

When we looked at the actual neurons involved in this, this is a neuron in a particular part of the brain in a control animal. This is that similar type of neuron in an alcohol animal. You can see that the bush, that elaborate network around the cell body, is hardly developed. So these connections, the events that are happening during the brain growth spurt, were disrupted by this, and it is a profound effect and talks to the caution that one should have concerning exposures during the brain growth spurt.

Our research has taken us to not only looking at drugs but looking at nutrition and using the procedure to look at formulas. What if we were to feed rats formulas that had different qualities of protein, in this particular case. The "P" group in this particular slide is "protein enriched." We can find that not only will we alter brain growth, but we can affect behavior as well. So, while there may be less dramatic effects in terms of malformations and things that you can see, the period of time when the brain is growing at that particular rate is a very volatile time in terms of the final outcome for that animal. I think our work has talked not only to drugs but has talked to basically what is necessary to build a brain, what is necessary to build a normal brain. We have been able to look at a variety of different factors involved in this: recovery factors, how does the brain respond when it is being insulted, and how can we maximize that or minimize that, and what will interfere with the brain's response to an insult?

One of the benefits of using this procedure as we developed it is that a variety of different research lines opened up. By using this surgical procedure of feeding animals, we are able to generate entirely new lines of research that were not available before. One particular line is, if we can feed rats with this particular procedure early in life, during critical periods, then we can overfeed them. One particular line was to make these infant rats obese and examine the question of, "Do fat babies remain fat?" What are the biochemical ramifications for being fat early in life?

This type of research line is not and was not available before the surgical procedure. So within developing and within the guidelines of my research topic, we were able to start spinning off separate lines that did not show up before, that we did not anticipate before, concerning issues that are important and issues that were not approachable before this.

The effect of formula feeding is another whole research area that now we can examine directly in terms of what is necessary in a formula for normal brain growth and for the development of a normal individual. Those are the lines of research that we have been pursuing under the NSF grant.

The CHAIRMAN. Thank you so much. We will now turn to Dr. John Knauss, who is the dean of the Graduate School of Ocean Sciences, at the University of Rhode Island, which of course is one of the Nation's premiere institutions for oceanographic research. As I understand it, Dr. Knauss, you are going to describe several of the NSF-supported research projects funded by the Ocean Sciences Program, including the research vessel *Endeavor*.

STATEMENT OF JOHN A. KNAUSS, DEAN, GRADUATE SCHOOL OF OCEANOGRAPHY, UNIVERSITY OF RHODE ISLAND, NARRAGANSETT, RI

Dr. KNAUSS. What I would like to do today is to focus on work that my colleagues and I have done over a number of years on the Gulf Stream. Much of that work is being done with our research vessel *Endeavor*.

The Gulf Stream is a feature which has captured our imaginations for well over 200 years, of sailors as well as scientists. Trying to understand the complexity of the Gulf Stream is certainly an interesting and worthy intellectual challenge, but it also has some importance in the following way. We are now convinced that the changes in the weather from year to year are controlled by ocean currents. One of the things we expect to be able to do in the next 30 years is to be able to predict those changes in ocean climate. Not whether it is going to rain in Salt Lake City in 1985 on July 4, but whether or not July will be a wetter year than normal and whether or not there will be more snow packed in the mountains in 1986 than in 1985, and that sort of thing, those long-range changes or, I should say, short-range climatic changes trends in the weather.

These are all controlled, we now know, by small perturbations in ocean currents.

The CHAIRMAN. We could sure use some help out there in Utah.

Dr. KNAUSS. The Gulf Stream, which is the mightiest of our ocean currents, at least in the Northern Hemisphere, is certainly a part of that picture. And trying to understand the perturbations of the Gulf Stream will lead us, we believe, eventually to be able to understand the changes in climate.

Let me start with the first picture of the Gulf Stream ever drawn. That was done by Benjamin Franklin, back in 1770, I believe. You can see the Gulf Stream as a mighty river in the sea, and we think of it as a river in the sea, transporting the heat from the south up to the north and then to the east (Fig. 1).[1]

One hundred years later, a Mr. Findley, would show the Gulf Stream as a small nozzle down here at Cape Hatteras and then

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[1] Fig. 1 through 8 appears on pp. 29-36.

spreading out in all directions to the east. That is how we thought the Gulf Stream looked maybe about 1870 (Fig. 2).

This is a picture drawn about 1970 (Fig. 3). What you see is a number of different pictures of the Gulf Stream. Each one of those patterns, if you could follow it, is the Gulf Stream at any particular time. What you are seeing is the edge of the Gulf Stream. The Gulf Stream itself is still 100 or so miles wide. But each time it meanders along so that it is still a river in the sea, but it does spread out as one goes. That is. the banks of the river. if you will, become very indistinct.

To make that picture was a lot of work. It required taking a ship down at the beginning, at Cape Hatteras, and moving up along the Gulf Stream, following the edge of the Gulf Stream, and measuring the temperature, not only at the surface but at depth, as you will see. There is a number of man-months of effort to make that kind of a picture.

Now we have satellites, and this is a satellite picture of the Gulf Stream, showing the surface temperature of the ocean as described by the satellite. The blue is cold, the green gets warmer, and the yellowish-reddish colors are the warmest of all. The white that you see in this picture and other pictures are clouds, and we cannot get away from that problem.

The CHAIRMAN. How was that taken?

Dr. KNAUSS. That is with a satellite.

The CHAIRMAN. That is a satellite picture then?

Dr. KNAUSS. That is not a picture. That is the sea-surface temperature——

The CHAIRMAN. As represented by colors?

Dr. KNAUSS. By colors. What the satellite does is to accept the radiation in the infrared, which determines what the temperature is. All we have done is essentially to color-code it. What the satellite gives us is the radiation information, and then we just put it into a computer, and the blue comes out cold and green and so forth, as you see.

If you want to make your computer a little more fancy—and you cannot see it quite so well there—you can get rid of all the other colors and leave the Gulf Stream looking almost like Franklin's Gulf Stream, essentially as a river in the sea, moving down there. But remember that this river in the sea, if you will, is going to move about from place to place.

This is a picture of the temperature of the ocean as we go across the Gulf Stream, where the red is the warm water and it gets cold as we go down (Fig. 4). The temperature is in degrees centigrade. We have what we call the "cold wall." You can almost see it there on the slide, where the isotherms drop dramatically straight down (Fig. 5). That is where the Gulf Stream really is. That is where the real edge of the Gulf Stream is. What happens at times, however, is that sort of a low, small layer of warm water gets off to one side, so you would get a false position on where the Gulf Stream is, if all you had was satellite alone (Fig. 6).

What we would like to be able to do is to figure out a way to keep track of where the real Gulf Stream is, without having to go out with a ship and make measurements on a very labor-intensive basis. We have a way of doing this now.

That, by the way, is a picture of our research vessel, *Endeavor*, which is owned by the National Science Foundation. We operate it and have operated it now for about 7 years. It is 175 feet long, carries a crew of 12, and we can carry about 16 or 18 on a scientific party. We keep it at sea about 280 days a year. There are about 13 ships like this in the academic fleet around the United States. We have one, the University of Washington has one, Oregon State, and so forth. They are very efficient vessels. I think they are the most efficient research vessels in the world, and most of these are supported by the National Science Foundation. Many of them were built by the National Science Foundation.

This is the device that allows us to know a little bit about where the Gulf Stream is, without going out and measuring the temperature directly. If you have ever been aboard a ship with an echo sounder, which measures the depth to the ocean bottom, what it does is send out a sound pulse. The sound pulse goes to the bottom and comes back, and you measure the time it takes for the pulse to go to the bottom and come back. That determines how deep the water is.

If you put an echo sounder on the bottom of the ocean and ping up to the surface and back and forth, you would measure the depth of the water, and you would think, therefore, if you did that, and you left it there for 6 months or so, you would always get the same depth. However, the speed of sound is a function of the temperature of the water. So if the water is warmer than average, it looks like the depth is less because the time for going back and forth is less. If the water is colder, then clearly it looks like the depth of the water is greater.

If we put an echo sounder on the bottom of the ocean, such as that device there, and we put it down and leave it there for about 2 months—all it has are some batteries, a sound source, and a tape recorder—it pings up on the surface and measures the apparent depth of the water. Then we go back about 2 years later and send a signal down to it. It drops its weight and pops back up to the surface, and we bring it home and then measure where the Gulf Stream was. Here is a series of these that we have put out across the range of the Gulf Stream, where we can keep track of the Gulf Stream, of the cold wall of the Gulf Stream, by this kind of a device.

We are checking this with the satellites because, by determining when the Gulf Stream spews off the edge, as it does, with a satellite as well as with this device, we hope eventually to be able to use the satellites as a true means of keeping track of where the Gulf Stream is, rather than sort of a false image of where the Gulf Stream is at times.

This is another device we have used for tracking the Gulf Stream. This is a drift bottle, only it is an underwater drift bottle. I will not go into the details, but we can send this down to maybe 2,000 feet. It goes along and sends out a sound signal every few hours and so forth, and we track it just like people track Russian submarines. That is, we have listening posts off the shore of land and on islands, and by triangulating on that sound, we can track that underwater drift bottle as it moves through the ocean.

The white lines you see there are where the Gulf Stream normally is, and you can get some kind of a cross-section of what the Gulf Stream is. From an earlier picture, we put that device, where is the red wiggly spaghetti line you see there in the center of the screen, that was in the middle of the Sargasso Sea. It sort of wandered around at random, more or less, for about 2 or 3 months. Then it got into the Gulf Stream and came quickly up to the Northeast. It popped out of the Gulf Stream, as you can see where that loop is, came back in a reverse pattern, got back into the Gulf Stream, and then moved on forth.

So now we find we not only have a river in the sea but we have a leaky river in the sea, if you will. That is, we can bring water in from one side, and we can pop it out on the other. We now have a program where we are doing this in a much more systematic way, where we are tracking these underwater drift bottles in the Gulf Stream on a regular and systematic way, trying to determine to some extent how the water flows in and out of the Gulf Stream as the Gulf Stream itself flows along.

The Gulf Stream does other kinds of wonderful things (Fig. 7). As it meanders along, as in the upper left-hand corner, where you see the Gulf Stream has a little dip to it, then it has a bigger dip a couple of weeks later. Then it breaks off and it has a little ring to it. These Gulf Stream rings are big. They may be several hundred miles across, and they have a life of their own.

Here is a picture of work we did about 10 years or so ago, showing (Fig. 8)—one of these rings from the Gulf Stream that broke off like that and followed it down for better than 2 years, when it finally came to pieces down off the coast of Florida. The Gulf Stream does these kinds of things also. These rings, by the way, pop up not only on the south side of the Gulf Stream but also on the north side.

Finally, I want to show you three pictures of the Gulf Stream in some of its real complexity. Again, this is a satellite photo of the surface temperature: You can see the Gulf Stream coming down to the south. As it gets up there into the middle of the screen, it looks like it is going in all directions. You see other kinds of strange things around it.

Again, if you play games with our computer, you can take the Gulf Stream out of it. Here is the Gulf Stream itself, with a meander pattern and a big blip and then another meander pattern. The one far over is just in the process of forming one of those big cold-core rings that we had before. The Gulf Stream is meandering very much, as you can see.

Now I put the rings back in. You can see, first off, there is a warm ring, which is brownish color, in the center, which is kind of elongated, ellipsoid, which is caught almost in the Gulf Stream. There is a second ring, over further to the left, which has caught some water and swept it up into it, almost like a hurricane does, sweeping water out of the Gulf Stream. It is a little less brown; it is more green because it is cooling off. Then finally, down here closer to New Jersey is a cold green ring of the Gulf Stream. Those rings probably have lives on the order of 6 to 9 months.

Further down to the south in something which we do not really understand because we have only seen it a few times in the last few months. It is essentially a swath of warm water which is being pushed out from the Gulf Stream.

Mr. Chairman, what I wanted to try to show very quickly are the kinds of things that we are able to do with new and modern techniques that we have in studying the ocean. We use as an example the Gulf Stream which, as I said, from the time of Benjamin Franklin has been the object of intense interest, and I hope to point out it is not only of great intellectual interest and curiosity but also, because of its importance in the long term, enabling us to understand how this heat transfer takes place. We hope it will tell us a lot about how the ocean interacts with the atmosphere. We hope that maybe in 20 or 30 years, by understanding more about such things as the Gulf Stream and other major currents in the ocean, to be able to do a better job of helping you with that snow problem in Utah. Thank you.

[The figures referred to as 1 through 8 follow:]

FIGURE 1.

LAND of the
ESKIMAUX's or LABRADOR
ATLANTIC OCEAN
VIRGINIA
SOUTH CAROLINA
GEORGIA
PART OF THE
GULF of MEXICO
ATLANTIC OCEAN
A CHART of The

FIGURE 2.

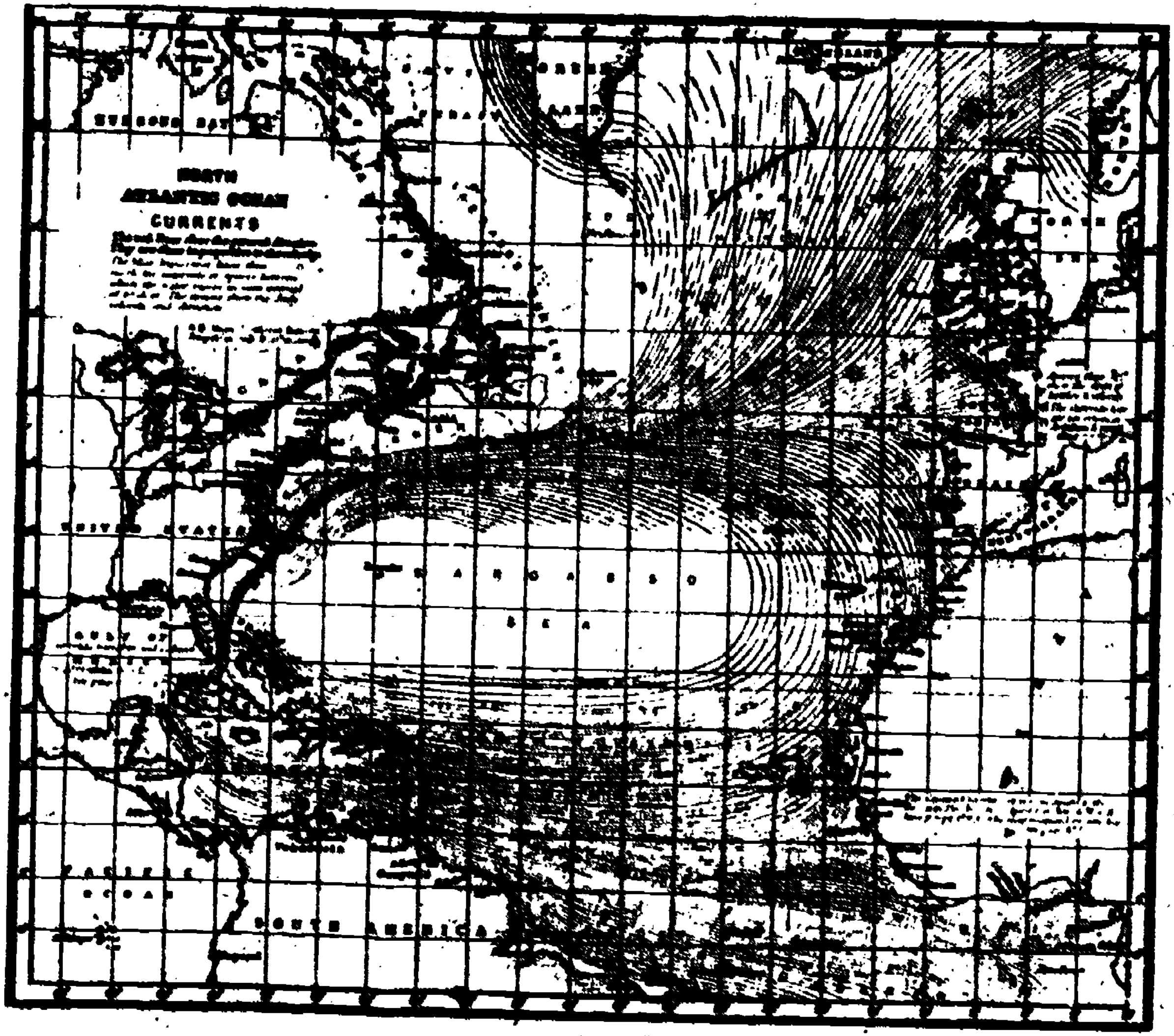
NORTH
ATLANTIC OCEAN
CURRENTS
UNITED STATES
SARGASSO
SEA
OCEAN
SOUTH AMERICA

FIGURE 3.

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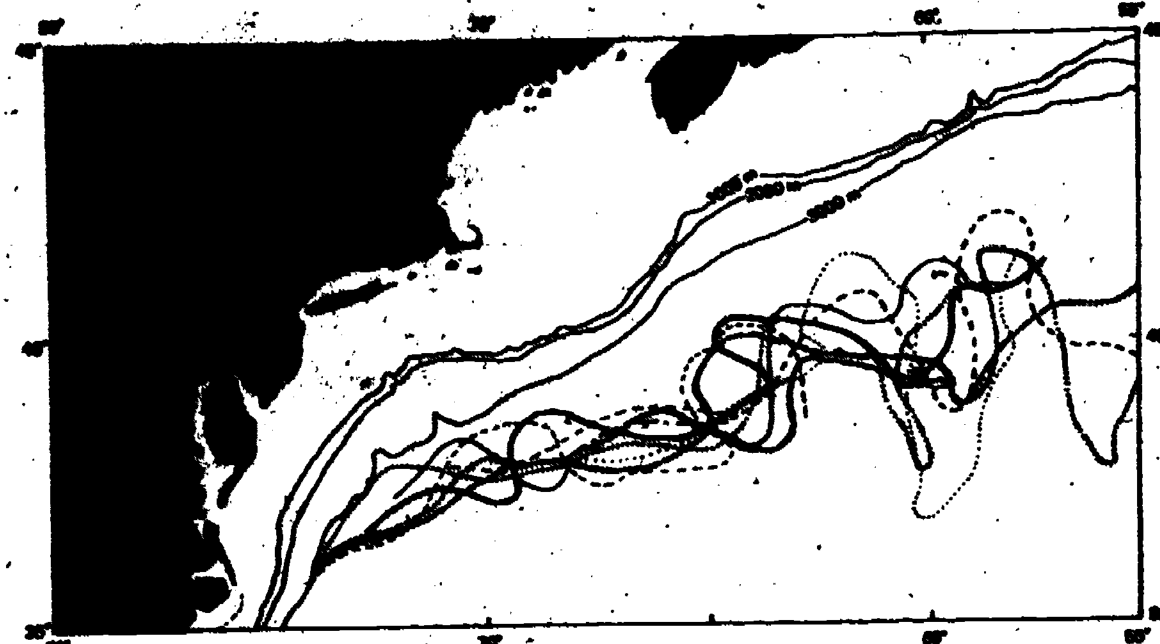


FIGURE 4.

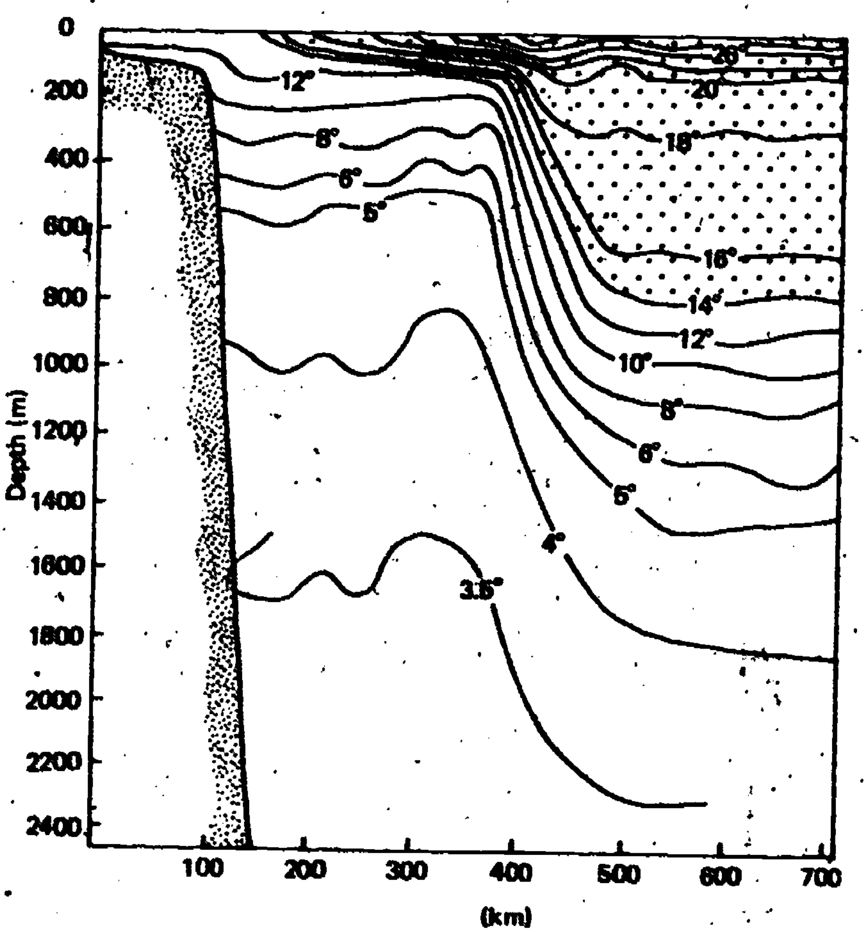
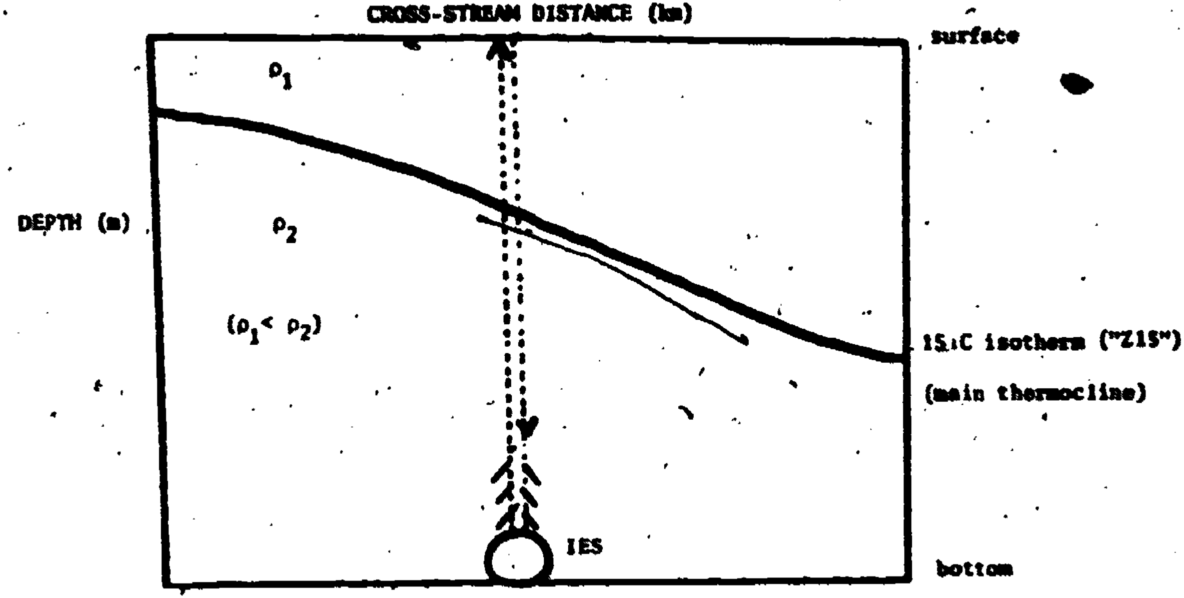

0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Depth (m)
100
200
300
400
500
600
700
(km)
12°
8°
6°
5°
3.5°
4°
26°
20°
18°
16°
14°
12°
10°
8°
6°
5°

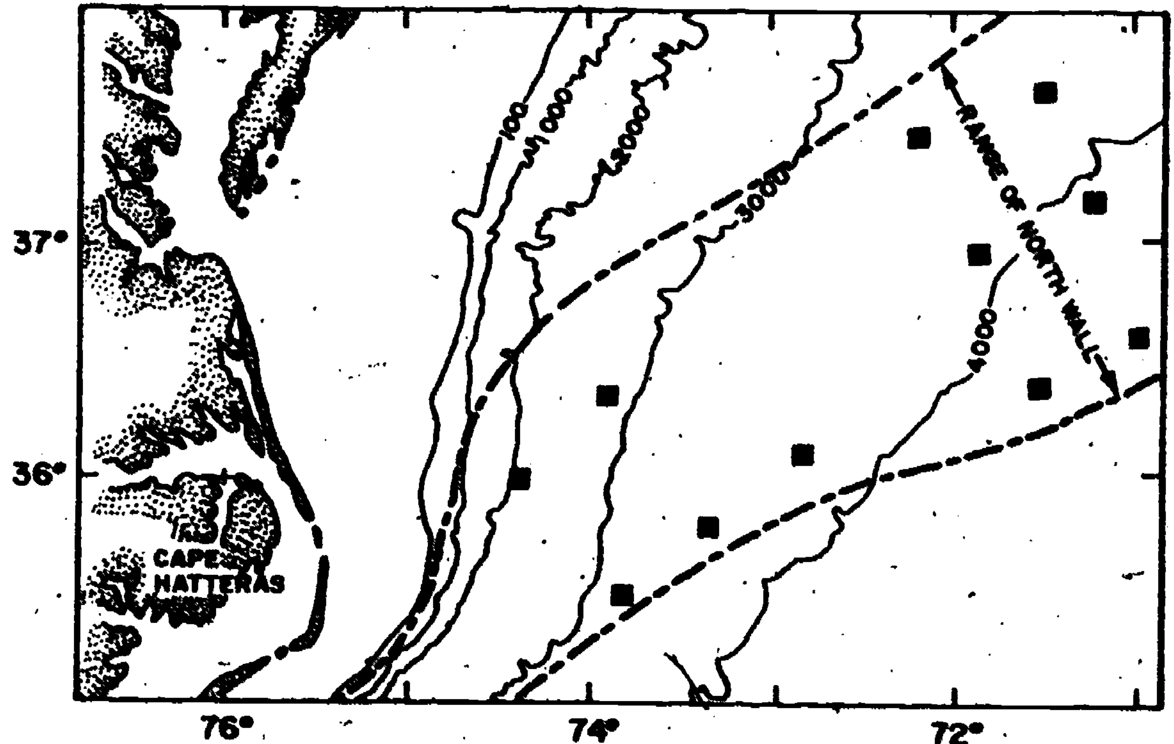
FIGURE 5.



CROSS-STREAM DISTANCE (km)
surface
ρ1
DEPTH (m)
ρ2
(ρ1 < ρ2)
15°C isotherm ("Z15")
(main thermocline)
IES
bottom

88

FIGURE 6.



100
1000
2000
3000
4000
RANGE OF NORTH WALL
CAPE HATTERAS
37°
36°
76°
74°
72°

33

FIGURE 7.

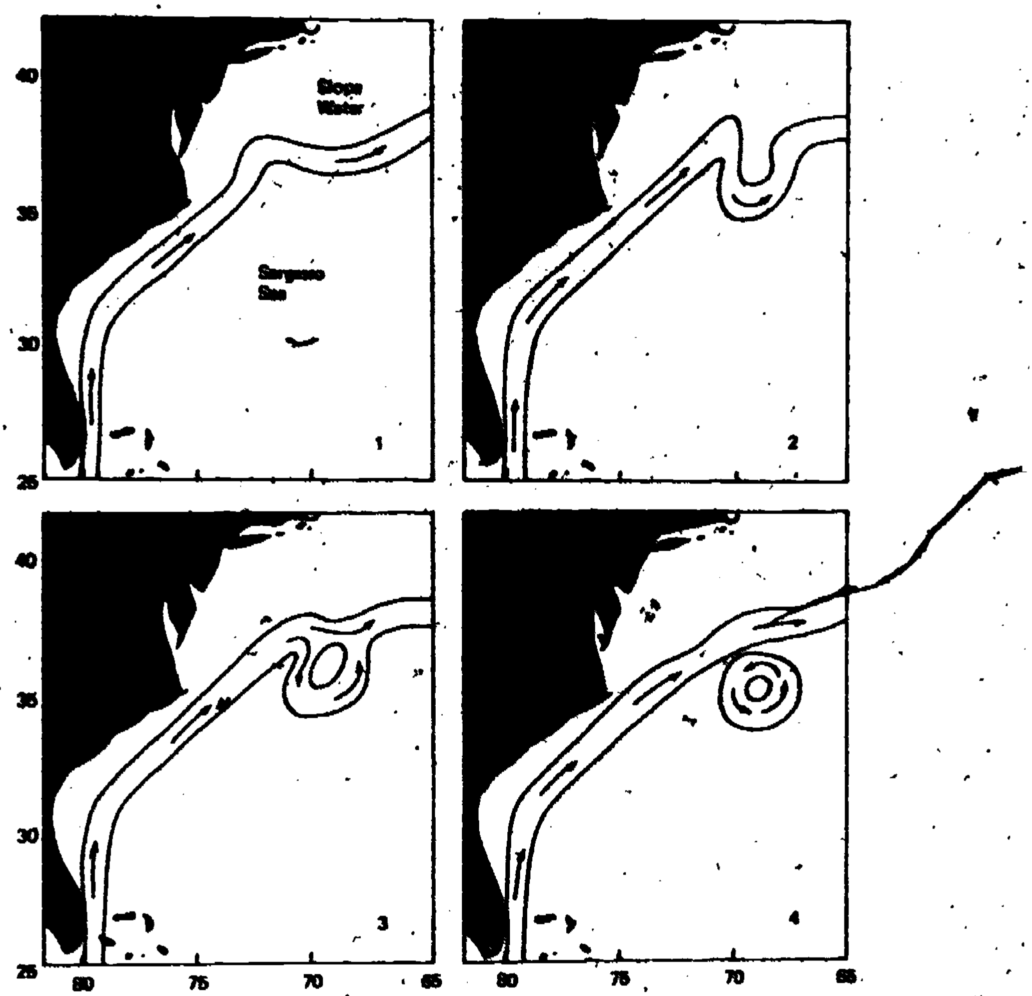


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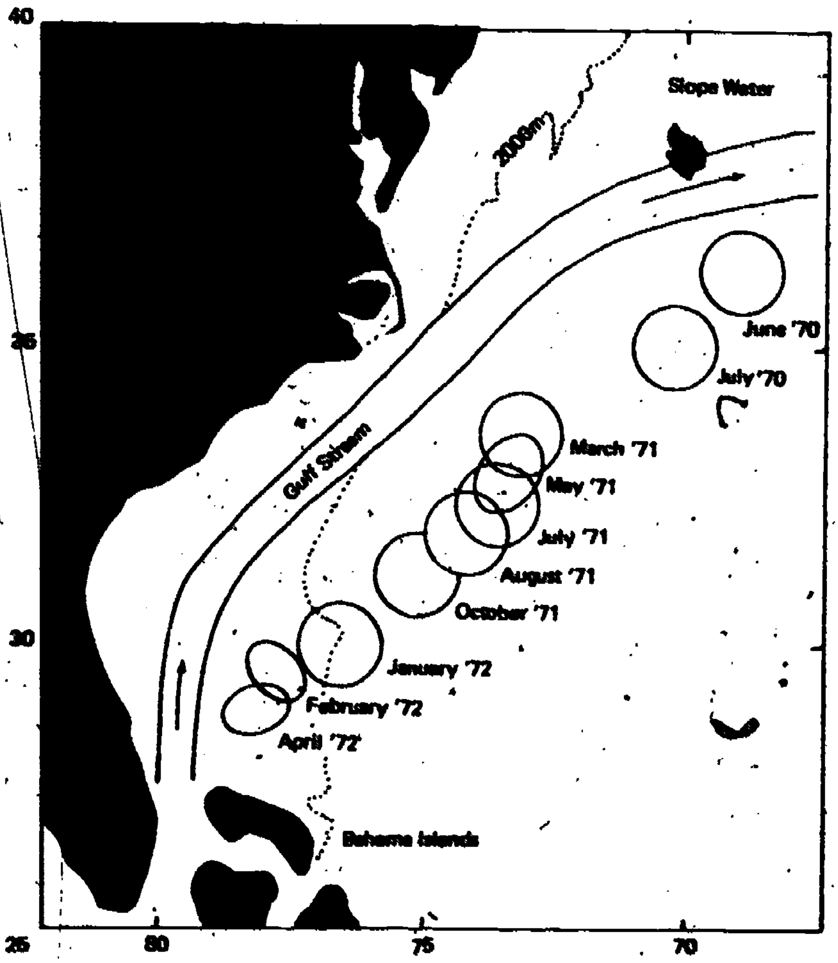
FIGURE 8.



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The CHAIRMAN. Thank you, Dr. Knauss. This has been very interesting so far.

Dr. Laurence Strong is research professor of chemistry at Earlham College in Richmond, IN. His research is funded as part of NSF's increased emphasis on improving research opportunities at 2-year and 4-year colleges and universities. As I understand it, this is a cross-disciplinary program, called research at predominantly undergraduate institutions. So we will turn the time over to you, Dr. Strong. We are very happy to have you here.

STATEMENT OF LAURENCE E. STRONG, RESEARCH PROFESSOR OF CHEMISTRY, EARLHAM COLLEGE, RICHMOND, IN

Dr. STRONG. The two grants that I have from the National Science Foundation are from the program called two and four-year college research instrumentation program, which I suppose now appears more as predominantly undergraduate institutions.

I might say a little bit about the institution where I am. It is a liberal arts college of about 1,000 students. It has a long history of sending students from the sciences on in to advanced degrees, to work as scientists in later years. The research that I am going to tell you about is a project that began nearly 20 years ago and arose out of some of the things that interested me in my teaching of chemistry.

During the past 10 years, approximately, I have had about 30 students, undergraduate students, who have participated in this work. In addition to the two grants from the National Science Foundation for instruments, I have also had a number of other grants from other agencies, mainly for supporting students during the summertime to work with me.

I might begin by indicating something of the significance of the kind of work that we are doing. It is a project that is concerned with trying to find out more about how individual atoms and small groups of atoms attach to a more complex molecule and affect the properties of the molecule. This is important in trying to design molecules for particular purposes.

One of the people who has been particularly active in this in recent years is Professor Hanch at Pomona College, who has developed a system whereby you can organize the data and predict biological activities of complex molecules from data about the individual parts of the molecule. His procedure is being used now increasingly by pharmaceutical firms, by manufacturers, designers of pesticides, and herbicides, and a variety of other substances of considerable use in our society. In fact, since I prepared my testimony, I have had a manuscript from him, just in the last couple of days, describing work that has been done recently in Japan.

One is to design a better bacteria static agent and the other is to design a better herbicide for use, I gather, in ricefields and such enterprises. The conclusion from this manuscript seems to be that these kinds of data and this system of organizing the data are extremely useful in making molecules that are as efficient as possible. This kind of work, in this case, was of concern to Japanese scientists and drug designers.

A good deal of work has been done in this area over many years by a great many different people, and a lot of information has been collected. Even so, it seemed to me several years ago that there are also items of data that are not available, either because people have not worked on them or because there simply have been too few instances collected to draw some useful generalizations. So we are, in a sense, trying to fill some of these gaps. My particular interest is in the energetics of the ionization of molecules.

The kind of molecule we have been working with I have here in a 100 millionfold magnification, as a molecular model such as chemists would use. This is benzoic acid, in which the black represents carbon atoms, the white represents hydrogen atoms, and the red oxygen atoms. The part which is of immediate interest, which we measure, is the ability of this hydrogen atom to be separated from the rest of the molecule or ionized. This forms the acidity of the molecules and, in this case, benzoid acid.

One reason for using is that it has this rigid framework, which actually represents six carbon atoms, the hexagon in my hand, and various atoms and molecules can be attached around the five positions that are indicated by the white hydrogen atoms. I have brought along one, for example, on which we have worked, which has two groups attached where my hands are to form dimethylbenzoic-acid, to use the chemists' terminology for it.

So what we do, what students have been doing, is to prepare in highly purified form one or another of these substances and then measure the acidity, measure the extent to which this atom is lost in the presence of various other groups attached to the molecule.

If I could turn on the overhead projector, it will show on the screen. This is a plot of some of our data for a group of methylbenzoic acids in which the benzoic acid has been numbered around this hexagon from 1, where the oxygens are, 2, 3, 4, 5, and 6. So the numbers on the right, 26, 236, and so forth, indicate the positions on the ring to which the methyl group has been attached. The line of dashes near the lower one-third of the plot is representative of benzoic acid.

The acidity increases as you go from bottom to top of this plot, and the numbers on the left and right axes are just the measures that are used of the acidity. So as we have put methyl groups on the benzoic acid, if we put 1 or 2 in position 3 or 4, down near the bottom, we decrease the acidity of benzoic acid. If we put the methyl groups in the 2 position or the 6 position, we increase the acidity of benzioc acid.

The thing that is of particular interest to us and what was not known before is represented by the group at the top. These are all acids which have not been the subject of study by anyone before, I guess in part because they were found to be difficult to study.

The 26 acid, which is this molecule here in my hand, if you add to it then methyl groups in the other position—3, 4, and 5—in every case they decrease the acidity compared to the one at the top. On the other hand, down a little further, you see one labeled No. 2, a methyl group in just the 2 position. If you add a methyl group in the 3 position, the 23 one, you increase the acidity. It is rather abnormal, unusual behavior.

From these curves, which I have shown here, one can deduce then a number of other properties of these acids, the energetics of the ionization, which is our particular interest but which I do not propose to describe in detail unless people have questions about it.

One aspect of the work—and one which grants from the National Science Foundation have been particularly helpful—lies in the fact that in order for these data to be useful, they have to be obtained at high precision. We customarily work with precision of about one one-hundredths of 1 percent. This is necessary in order to be able to do the calculations and the statistics from which we can get reliable information about the energetics. We have been able to develop a way of making measurements in almost every case through this kind of precision. So undergraduate students in fact are exposed to work of this precision which, among other things, is primarily paying attention to a lot of details in order to be sure that the reliability and the precision are maintained.

One other interesting sidelight to this is the fact that when you examine the energetics, you find that the ionization of these acids is controlled in many cases by the fact that during the ionization process something happens that increases the orderliness, the arrangement, of the system. The explanation, which has been advanced by others in years past, is that this is due to what is happening to the water in which these acids are dissolved. So, another result growing out of our work is the information about the nature of water, which is one of the important chemicals, one of the important substances, with which we all deal and which rather surprisingly is still not understood very well at the molecular level.

I would like to say a little bit, in conclusion, about the kind of assistance that the National Science Foundation grants have provided. We have had, as I have said before, two grants to buy instruments. They were primarily helpful in obtaining the kind of precision that we needed. We have also been able to borrow equipment from Wright State University and from Illinois Institute of Technology. Earlham College is perhaps fortunate among the smaller colleges in having rather well-equipped laboratories. We also have a pretty good science library. In fact, one of the grants that is listed as an appendix to my prepared statement was a grant to the college to bring other librarians from colleges and universities to workshops on how we operate our science library at Earlham.

Support from the National Science Foundation and particularly from the 2-year and 4-year College Research Instrumentation Program has been an important aspect of our ability to carry on work. I also included a list of the various grants that have been received by people at Earlham College, and a number of these are of this kind, as well as others such as I mentioned for the Science Library Training Program.

When colleges and universities are examined in relation to the baccalaureate origins of doctoral degrees, there is a preliminary study which indicates that out of the leading 25 institutions in this regard, 15 of them are 4-year colleges. Earlham is not in those first 25, but it is not very far below the first 25.

It also would appear that a considerable number of the individuals that are currently teaching in colleges and universities in the sciences are graduates of 4-year colleges. At Earlham, we found, in looking through our graduates in chemistry, that 23 of them, in the years from 1963 to 1977, are now teaching in colleges and universities. So liberal arts colleges and 4-year institutions are important sources of manpower and womanpower for the further development of science education at all levels in our country.

We are also one of a group of colleges in the Great Lakes Colleges Association, 12 colleges, and these institutions have received about a half million dollars during the past year from the 2- and 4-year College Research Instrumentation Program. Somewhat similar activities have occurred at our sister association, the Associated Colleges of the Midwest. So for these two, this grant program has been a useful and helpful kind of thing.

So I would urge that provision be made in the legislation in the future so that the National Science Foundation continues to provide support for scientific research by faculty and students in the 4-year colleges. We are certainly indebted to this committee—I believe it was this committee—that originally formulated the legislation on the 2- and 4-year College Research Implementation Program some years ago.

Unfortunately, our experience has been one that we think demonstrates rather clearly that without specific inclusion in the legislation, these 4-year colleges are often discouraged from the granting process and that the number and magnitude of the grants that they receive, in years when such program does not operate, decline.

I would also indicate, finally, that as I understand it, Federal support for undergraduate science education at the present time is zero at the Foundation. Thank you very much.

[The prepared statement of Mr. Strong follows:]

STATEMENT BY DR. LAURENCE E. STRONG, RESEARCH PROFESSOR OF CHEMISTRY, EARLHAM COLLEGE

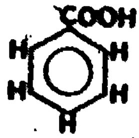
Mr. Chairman and members of the Committee:

I am a Professor of Chemistry at Earlham College. It is a liberal arts college with a student body of about 1000 and is located on the eastern edge of Indiana. It has had a long history of graduating students who go on to advanced degrees in the Sciences. The research about which I have been asked to tell you something is a project that began nearly twenty years ago and arose out of some of my interests in Chemistry that had developed through my teaching. During the past ten years about 30 students have participated in the work. Support has come from a number of sources including two National Science Foundation grants, a grant from the Petroleum Research Fund, two grants from Research Corporation, funds from the duPont Company, and grants from the Professional Development Fund of Earlham College. Before describing the research itself it is appropriate to give a brief description of how the results of the research can be useful to others.

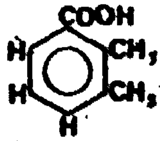
The project is developing information about how various atoms or groups of atoms contribute to the acidity of a molecule. In a general sense, such information leads to a better understanding of chemical behavior. For complex molecules made up of a number of parts it is helpful to know how the different parts contribute to the properties of the entire molecule. Thus Professor Hansch at Pomona College has developed a way of predicting such important properties as the biological activity of a substance from knowledge of the constituents that make up the molecules of the substance. His procedure is being widely used in the devising of new pharmaceuticals and other useful substances in a wide variety of fields. While our work is concerned chiefly with measurments of acidity there are reasons to believe that the results are directly applicable to other properties as well including those used in the strategy developed by Professor Hansch.

A great deal of work has been done over the years by many people developing data to show the effect on the properties of a substance when an atom or a group of atoms is added to a molecule of the substance. Even so there are some quite fundamental kinds of data that have not been obtained or have been obtained in too few instances to permit the drawing of reliable generalizations. One major set of such data has to do with the energy changes that accompany the ionization of an acid, the process that we recognize as acidity. It is the energetics related to acidity that is the main subject of our research at Earlham College.

The chemicals we study are benzoic acid and some of its many modifications. Benzoic acid lends itself to such studies in part because it is a molecule having a rigid framework with five sites to which a variety of other atoms and groups of atoms can be attached. Probably the best known modified benzoic acid is aspirin. The adjoining figure is a schematic representation of a benzoic acid molecule such as a chemist might use and shows the points of attachment numbered for identification in the naming of modified benzoic acids. The acidity arises from the -COOH portion of the molecule. One example of a modified benzoic acid is represented by the schematic for 2,3-dimethylbenzoic acid.



Benzoic acid



2,3-Dimethylbenzoic acid

Each of these modified benzoic acids is prepared in sufficiently pure form and its acidity determined in water over a range of temperature, usually from the freezing point to the boiling point of water. This determination is made through measuring the electrical resistance of the water solution at each of 21 different temperatures. A plot of some of our data is presented in the attached figure. It shows acidity increasing from bottom to top of the plot for a number of benzoic acids to which one or more methyl groups have been attached at the points on the ring indicated by the numbers at the righthand end of each curve. The vertical scales represent two different ways of describing acidity in quantitative terms. The dashed line near the bottom of the plot is for benzoic acid itself. Of the 19 possible methylbenzoic acids the figure presents data for 13. For most of the acids in the figure we believe the measurement precision is about 0.01%. At present we have corresponding data for seven of the nineteen possible fluorobenzoic acids and 3 of the nineteen possible hydroxybenzoic acids. Work is continuing to measure more acids.

High precision is essential to our studies and it has been lack of high precision that has frustrated most others who have attempted to obtain similar data. With data of sufficient precision it is then possible to analyze the data for each acid to obtain several different characteristics of the energetics of the acidity, that is the ionization process. The analysis is done by statistical procedures which have been the subject of discussion and disagreement among scientists for many years. In the last couple of years we have been developing a new method of doing the calculations which we are able to show gives more reliable results than earlier methods. This work has been done in conjunction with Professor Frank Halliwell of the University of East Anglia in Norwich, England.

Chemists find one interesting aspect of these acids and their behavior in water is that the ionization process leads to an increase in the orderliness of the system. This ordering can be measured in quantitative terms and chemists refer to it as entropy. The explanation of the increased order produced when an acid ionizes is believed to be the effect that the ions formed have on the surrounding water molecules. Thus one further result of studies such as ours is to give information about the nature of water. Water, surprisingly, is still for chemists one of the incompletely understood substances in spite of much study over many years.

Essential to our research are appropriate instrumental facilities and NSF has provided important assistance with two grants during the past five years through the program for scientific equipment for two and four year colleges. It has also been possible for us to borrow equipment from Wright State University in Dayton and Illinois Institute of Technology in Chicago. Fortunately, Earlham College laboratories are reasonably well equipped with a number of useful instruments including spectrometers, chromatographs, balances, and a broad range of glassware for chemistry.

Most important for the pursuit of modern research is easy access to the scientific literature. Earlham College maintains a good science library, unusual among small colleges. We are also fairly close to a larger science library at Miami University and interlibrary loans are easily arranged with still other libraries.

The scientific data that we gather requires extensive calculation and statistical analysis to take full advantage of the results. With over 300 numerical items of data for each acid requiring hundreds of calculations, processing the data is only feasible with a computer. The College has an adequate computer facility for our purposes and makes it freely available.

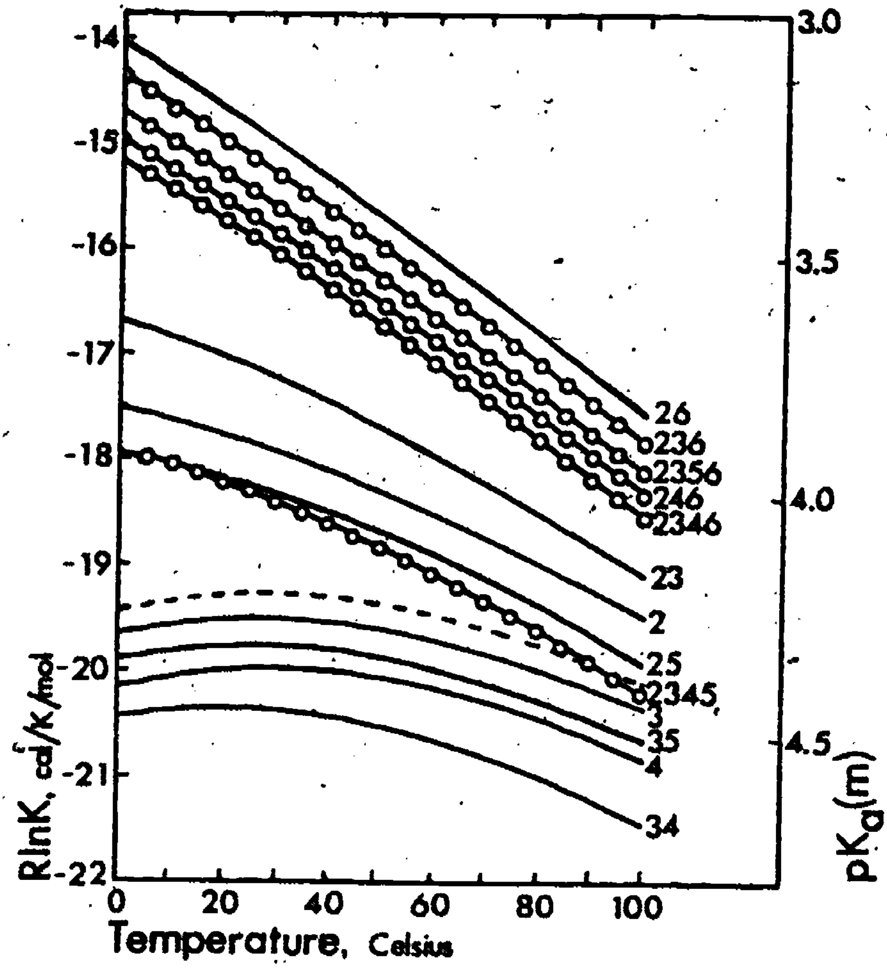
Support by grants from the National Science Foundation has been an important contribution to our ability to carry on research. Appendix A lists the grants that Earlham College has received in the past ten years from the National Science Foundation. The research is not only a contribution to scientific knowledge but also to the education of undergraduates. A number of liberal arts colleges carry on similar kinds of activitites and in so doing stimulate young people to continue into advanced training and careers in the sciences and related technical fields. We, in the liberal arts colleges, believe that these activities and students are important contributions to our nation and to society generally.

When the institutions are examined that provide the baccalaureate degrees for those who subsequently obtain the doctorate it is found that the out of the leading 25 institutions fifteen are four year colleges. This ranking is on the basis of the number of PhD degrees per baccalaureate degree. Furthermore a major number of those individuals currently teaching in colleges and universities are graduates of four year colleges. For Earlham College we find that 23 of the persons graduating between 1963-1977 are now teaching in colleges or universities.

Earlham College is one of 12 colleges making up the Great Lakes Colleges Association. These colleges comprise more than 20,000 students. In the past five years 7 of these college have received over a half million dollars from the two and four colleges scientific equipment program of the National Science Foundation. Somewhat similar activities have occurred in the eleven Associated Colleges of the Midwest.

We urge you to see that provision is made in legislation so that the National Science Foundation continues to provide support for scientific research by faculty and students in the four year colleges. We are greatly indebted to the foresight of this committee for formulating the legislation in this way. Sadly, experience has clearly demonstrated that without specific inclusion in the legislation these four year colleges are almost completely excluded from the granting process.

Acidities of methylbenzoic acids are shown as a function of temperature. The acidity increases from bottom to top in the figure. The scales on the right and left axes are quantitative description of acidity.



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Appendix A
EARLHAM COLLEGE
NATIONAL SCIENCE FOUNDATION GRANTS
1974-1984

*June 1, 1983 — $20,311 — Laurence Strong

Densitometer and Digital Plotter for Thermodynamic Studies.

September 1981 — $ 5,024 — Paul Ogren

Interdisciplinary Units on Modern Theories of Matter and on Crystalline Solids.

*September 1981 — $ 4,249 — Charles Martin

Preparation of Videotapes of Optical Properties of Mineral and Pollen Grains for Use in Optical Mineralogy and Palynology Courses.

*June 1, 1981 — $ 5,800 — Katharine Milar

Purchase of TRS-80 Microcomputer for Studies of Phencyclidine Effects on Memory.

*July 30, 1980 — $10,305 — Wolfgang Christian

Acquisition of Infrared Fluorescence Apparatus.

July 1, 1980 — $16,853 — John Iverson

Systematics and Evolution of the Turtle Family Kinosternidae

*May 16, 1980 — $14,714 — Kent Van Zant

Microscope for Palynological Research.

*March 28, 1980 — $25,000 — Paul Ogren

Acquisition of a Nuclear Magnetic Resonance Spectrometer.

*January 15, 1980 — $10,000 — Wilmer Stratton

Purchase of Atomic Absorption Spectrometer.

*June 6, 1979 $25,000 Laurence Strong

Conductance and Thermodynamics in Relation to the Molecular Structure of Selected Weak Acids.

March 4, 1977 $ 6,280 Charles Martin

Undergraduate Research Participation.

September 21, 1977 $124,800 Jerry Woolpy

Development of Delphi.

June 11, 1976 $50,600 Thomas Kirk

The Development of Course Related Library and Literature Use Instruction in Undergraduate Science Programs.

May 15, 1975 $ 9,800 David Weening

Improvement of Quality of Undergraduate Science Instruction through Acquisition of Instructional Scientific Equipment.

* Grants received through the Two and Four Year College Program of NSF

Summary of Amounts:

$20,311
5,024
4,249
5,800
10,305
16,653
14,714
25,000
10,000
25,000
6,280
124,800
50,600
9,800
$326,736

3/31/84

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The CHAIRMAN. Thank you very much.

Senator Quayle would like to make a comment or two.

Senator QUAYLE. Thank you, Mr. Chairman. First of all, I would like to thank you for holding these important hearings on the National Science Foundation, an interest which I know that you share with the rest of us. I know that we will move forward to move this bill as soon as possible. I thank you for your concern and also your leadership on this issue.

Second, I would like to thank Dr. Strong, who is a constituent of mine, for very fine testimony. He represents a fine university, and he outlined the need for funding and for what the National Science Foundation can do very specifically.

I might just ask you one quick question. If in fact Earlham College did not have this $328,736 in grants from the National Science Foundation, are there other resources that would be available to pick this up, or would we in fact just lose these types of research and development programs? Could you give us, from your perspective and from your school's perspective, what would happen if in fact these grants do not come forward?

Dr. STRONG. I would say my own experience is that the grants I have had from the National Science Foundation have been a major part of the dollars that I have been able to use in my own research, and I am sure that is true in the other instances as well, in the other grants that the college has had. As I indicated in my prepared statement, I have had grants from other organizations, funding agencies, but these in general are smaller ones. In most cases, they have been primarily to support an undergraduate student during the summer but not for the purchase of major instruments.

Senator QUAYLE. But for you to perform at the level of activity of which you are capable, as you have done in the past, this assistance from these programs are absolutely essential; is that correct? Would you characterize it in language that strong?

Dr. STRONG. Yes. It has been essential.

Senator QUAYLE. Mr. Chairman, I do have a statement that I would like to ask be put in the record. I have to depart, but before your next witness testifies, I might point out that I am very interested in getting fundamental engineering as more of a priority within the National Science Foundation. There is not only some of the research that can be done at Earlham College, but Purdue University and other schools around the Nation. We are in the technology age. Some people refer to it as the information or the high-tech age, and I think engineering is a very strong backbone that sometimes gets overlooked a little bit.

I will pursue my specific recommendations with the chairman and other members of the committee at a later date, but I would ask to have my statement included in the record at the appropriate place.

The CHAIRMAN. Without objection, we will order that, plus the statement of Senator Strom Thurmond as well.

Senator QUAYLE. I thank the Chair, and I appreciate your having this hearing.

[The prepared statements of Senators Quayle and Thurmond follow:]

Statement of Senator

Dan Quayle

NSF Authorization Hearing

April 4, 1984

Mr. Chairman, it is a pleasure to be holding a hearing today on the authorization levels for the National Science Foundation (NSF) for Fiscal Year 1985.

I'd like to commend my good friend from Utah, and Chairman of this Committee, for holding these hearings and for taking such an interest in this very important federal agency. I would also commend my colleague on his efforts and work in introducing the Administration's bill to authorize appropriations for the NSF for FY '85. I hope we can see speedy consideration of this bill in Committee and on the floor of the Senate and send a bill to NSF for the first time in several years. I know the Chairman of this Committee has been working with our colleagues on the Commerce Committee to come to an agreement on the jurisdiction of the NSF and I am hopeful that we can find common ground and do what is best for the NSF.

It pleases me to be here today to hear testimony from all the witnesses, and particularly from Dr. Laurence Strong, Research Professor of Chemistry at Earlham College in Richmond, Indiana. I look forward to all the testimony.

Before we begin, I would like to mention a bill that I have just introduced to amend the Organic Act of the National

Science Foundation. This bill, S. 2525, would emphasize within the NSF the importance of fundamental engineering research, necessary to keep our country competitive in industry and other technological fields. Fundamental engineering research generates future technology from scientific knowledge through investigation of systems, manufacturing processes, materials and methods. My bill would also make engineering education a priority for the agency. We have a serious shortage of engineering faculty at our nation's institutions of higher education, as well as a shortage of undergraduate and graduate engineering students.

The National Science Foundation and the National Science Board both have expressed their support for the language contained in S. 2525. I hope this Committee will consider S. 2525 favorably in the near future.

Again, Mr. Chairman, I appreciate your holding this hearing today, and I look forward to learning about the NSF supported research projects our witnesses will be discussing today.

REPORTER

STATEMENT BY SENATOR STROM THURMOND (R-S.C.) BEFORE THE SENATE LABOR AND HUMAN RESOURCES COMMITTEE REFERENCE HEARING ON RE-AUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION, 430 DIRKSEN SENATE OFFICE BUILDING. WEDNESDAY, APRIL 4, 1984, 10:00 A.M.

MR. CHAIRMAN:

It is a pleasure to receive testimony concerning the National Science Foundation and the research achievements of that agency.

The people of the United States and throughout the world have benefited enormously from the scientific research that has taken place in this country.

The United States today has the highest standard of living in the world, and this is due, in large part, to the efforts of our scientific community.

For many years, we have been the world's leaders in the field of science, and if we wish to remain in this leadership role, we must maintain a strong commitment to research.

Mr. Chairman, I believe that the President has displayed his committment to research in science and engineering by proposing a 13.6 percent increase in funding for the National Science Foundation in fiscal year 1985. Through the grants and contracts for research provided by this agency, significant advances may result in areas such as national defense, industrial productivity, health, energy and agriculture.

Today we will hear from some of the researchers who are working in these and other important areas. I commend them for their excellent work and look forward to their testimony.

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The CHAIRMAN. If I could just ask you one question that was bothering me while you were speaking, why is it helpful to know what increases the acidity of these molecules?

Dr. STRONG. The acidity itself is probably not of immediate interest to, say, a pharmaceutical designer of a drug, but the presumption is—and there is a good deal of evidence to support this—that once you have determined the effect of a particular atom or group of atoms added to a molecule on the acidity, that same magnitude of effect will be produced for any other activity that this or another simiiar molecule may have. Whether we then later measure acidity or some reaction rate or some effect on a bacterium, we will see the same kinds of changes in the effect produced by adding an atom or molecule. It is a generalizable property, once you have measured it.

We pick a system that is easily handled, as far as the measurement is concerned, to get the initial data. Those data can be used in a variety of other kinds of reactions, particularly those of interest to the designer of a bacteria static agent or a pesticide or a herbicide.

The CHAIRMAN. Thank you. That is interesting.

Dr. Richard Claus is associate professor of electrical engineering in the College of Engineering at Virginia Polytechnic Institute and State University. You have held several NSF grants, funded by NSF's Electrical, Computer, and Systems Engineering Program. I understand you are going to give us an illustration or at least a presentation this morning on fiber optics.

STATEMENT OF RICHARD O. CLAUS, COLLEGE OF ENGINEERING, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, BLACKSBURG, VA

Dr. CLAUS. First, I would like to introduce myself and my function and my background and then describe briefly what my support from NSF has been in several different areas, and then specifically target some of the results of that support, and then finally briefly discuss some of the scientific developments that we have come up with.

I am 32 years old. I graduated from Johns Hopkins in electrical engineering in 1977, and since then I have had support from the National Science Foundation in five different grant programs. The first of them was an initiation plan in engineering. That was followed by a regular NSF engineering research grant, two research equipment grants, and since my function at Virginia Tech is both research and teaching, I also pursued and was awarded an instructional laboratory equipment grant. So NSF money in my program, in fiber optics and in acoustics, has supported both research and instruction.

Other research support for that same work has come from NASA, the Navy, the Air Force, and several industries.

The specific results of that support can be divided into two categories, one in research and the other in instruction. In research, that support has not only supported my efforts but also the efforts of approximately two graduate per year, and of those 12 graduate students that have worked with me, 11 have been U.S. students and one has been an international student. We have also produced some things that NSF likes to see: papers. We have averaged approximately one paper a month, review papers, many invited, and also a book in that time. Specific engineering results also have resulted in five patents, and we are working on two more, so that the work that we do has not only been basic research in fiber optics but it has also been applied research that has resulted in some usable systems. We have also received six NASA awards for that research in fiber optics.

On the instruction side, we have done several things. One is in tying the research money from NSF to direct undergraduate and graduate instruction, we have developed an instructional lab in fiber optics and in acoustics, which has served approximately 150 students in the last 4 years. Also associated lecture courses that have serviced approximately 300 students, and that support from NSF and the research supported by NSF has spawned industry cooperation in these areas, which has helped us quite a bit.

Let me briefly discuss some of the scientific developments that we have come up with. I have appended a modest description in technical terms of the work that we have done. The first thing we have done in fiber optics has been to use fibers not in the communications area but in the noncommunications area of sensors. We have used embedded optical fibers in aerospace structure material to determine the stress on the material and predict the failure and lifetime of the materials. Specifically talking about composite materials, composites are more or less like plastic plywood—very high strength-to-weight ratio, very good in low-weight-required areas. What we have done is embed fibers in a matrix inside panels of these composites and then looked at the ways that optical information transmitted through the fibers changes when you subject the composite material to strain and stress.

In doing that, we have had to work with a number of different optical modulation and demodulation schemes, which has led to the development of several optical instruments for the measurement on another line of metal surfaces and polymer surfaces. We have also looked at cracks in composites and how cracks propagate in composites and the detection of those cracks with optical fibers.

The second area that we have considered has been in acoustics, instead of in optical fibers. The mathematics and the physics behind the propagation of waves in acoustic lines, as opposed to fiber optic lines, is very similar. We have looked at waves specifically that travel on boundaries between pairs of solid materials. These are acoustic waves, ultrasound waves. They are characterized by hortical motion that with respect to the boundary between the solids is both up and down and back and forth, much like motion that you experience when you go to the beach and you stand out several meters offshore and you move up and down and back and forth. By measuring the components of motion of those waves, we are able to determine a number of properties of not only wave propagation but also the interface between the materials that support the waves.

Specifically, you can use changes in the properties of those waves to evaluate a glue bond that exists between the materials or weld that exists between the materials. You can also use waves such as this for electronic signal-processing devices, and these waves also have applications in seismology, where you consider the transmission of acoustic waves between large masses of rock with different acoustic properties. So this study has had applications in a number of different areas.

Another result of our work has been the development of a new type of ultrasound transducer that can be used for scanning tumors or fetuses. The new type of transducer uses results that we came up in our fiber optics research and transferred to the ultrasonics area. The new type of transducer generates an ultrasound field that is very easily detected and very easily calculated using signal processing techniques through a computer. That ultrasound transducer is one of the devices that we patented as a result of our research.

We have also developed several optical instruments just of general interest, with no real application other than the fact that they let us do our research a little more easily. These techniques are interferometric; they are more or less optical phase-measuring instruments. They have led us, for instance, to measure angstrom particle displacements of material surfaces without worrying about background vibrations of the entire surface. With an instrument like this currently, one industry is monitoring the motion of an optical fiber in a feedline assembly with a one angstrom sensitivity remotely from across the room using a laser source.

Finally, we have investigated the characteristics of optical fibers, both theoretically and experimentally, which make them useful as sensors of both pressure and temperature. Specifically, the measurements that we have made, the parallel measurements that others have done as well, include measurements of the amplitude of optical signals that are transmitted through the fibers, the polarization of the optical fields that travel down the fibers, and most recently, we have taken a look at changes in the time of travel of optical pulses that are transmitted from one end of a fiber to the other end. If you analyze the changes in the time of travel, or the delay of those pulses as they travel through the fiber, you are able to infer either the temperature of the medium that the fiber is embedded in or the pressure that is induced on the fiber.

[The prepared statement of Dr. Claus follows:]

Name:	Professor Richard O. Claus Department of Electrical Engineering Virginia Polytechnic Institute and State University
Age:	32
Education:	Johns Hopkins University, Ph.D., Electrical Engineering, 1977
Research area:	Guided wave optics and ultrasonics

NSF Support:

Engineering Research Initiation Grant	$25,000	1978-80
Engineering Research Grant	99,703	1980-83
Specialized Research Equipment Grants (2)	93,846	1978,1981
Instructional Laboratory Equipment Grant	34,600	1979-80

Results of NSF Support:

Research

- 12 graduate students supported (11 US, 1 international)
- 84 technical papers published
- 5 patent disclosures and patent applications

Instruction

- Developed instructional laboratory in fiber optics and electro-optics (150 students in 4 years)
- Developed associated lecture courses (300 students in 4 years)
- Developed industry cooperation in these areas

Specific Technical Developments:

- Developed new methods for testing the loading and potential failure of aerospace materials using embedded optical fibers.
- Obtained first direct measurements of acoustic waves which travel on the boundaries between solid materials. These waves have potential applications in the evaluation of welds and glued joints, in electronic signal processing devices, and in seismology.
- Demonstrated a new type of ultrasound transducer which has improved performance in biomedical scanning applications.
- Developed several new optical instruments for the inspection of metal surfaces for surface and subsurface defects.
- Investigated the characteristics of optical fibers which make them useful as sensors of pressure and temperature.

STATEMENT OF DR. RICHARD O. CLAUS

TECHNICAL SUMMARY

Ultrasonic Interface Waves

Part of my research funding from the National Science Foundation has supported the investigation of guided elastic waves known as interface waves which travel along the boundaries between solid materials. Like waves in water, interface waves have both up-and-down and back-and-forth components of particle motion which decrease in amplitude with distance into both of the materials, and their wave energy is confined to a region near the boundary. Although the interface waves between most pairs of solids are leaky so they lose some of their energy into the materials as they travel, unattenuated interface waves called Stoneley waves may be supported on the boundary if the material properties of the two solids are suitably related. Ultrasonic leaky and Stoneley interface waves have potential engineering applications in the nondestructive evaluation of critical aerospace structures, acoustic wave signal processing devices, and long acoustic wave delay lines used in communication systems. My research has involved measurements of the characteristics of these waves which determine their usefulness in these application areas.

Specifically, under NSF sponsorship, my graduate students and I have obtained the first direct measurements of ultrasonic interface waves. We have used mode conversion to and from surface acoustic waves to generate and detect leaky interface waves on steel-titanium and titanium-aluminum boundaries. On plane boundaries we observed efficient conversion from surface waves on the denser material and from grazing angle shear waves in the lighter material. We have demonstrated the nondestructive evaluation potential of such interface waves in two ways. First, by measuring variations in wave speed versus the compressive stress applied to metal specimens in contact, we have shown that interface and Stoneley waves are sensitive to conditions along the bondline. Second, using surface wave conversion at a corner of a solid specimen block and axially symmetric Stoneley waves on a tapered metal pin, we have observed wave interactions with surface and bulk material defects which are perpendicular to the bondline. In addition, we have used interferometric laser detection methods to observe the particle motion of interface waves directly on the boundaries between transparent materials such as glass and fused quartz in both smooth and welded contact. These direct optical scanning measurements have allowed us to better understand the processes involved in interface wave generation, reflection, and attenuation.

Optical Fiber Sensors

Equipment provided by NSF research and specialized equipment grants has also been used to investigate the performance of optical fibers as sensors of temperature and pressure. Our main effort in this area has been in the development of techniques which use embedded optical fiber waveguide to determine the stress and predict the possible failure of composite material structures. Such techniques could offer significant advantages over conventional evaluation methods for several reasons. First, if the fibers are embedded in the composites during manufacturing, they will allow the nondestructive inspection system to be "built in." Second, since the elastic properties of optical fibers are somewhat similar to those of the fibers used in some composites, composite material properties may not be degraded. Finally, optical fibers are a sensitive sensor of both stress and ultrasound.

Our research has led to developments in two areas. First, we have demonstrated a multiple fiber system which uses coherent detection techniques and computer processing to determine the two-dimensional stress distribution on a panel of composite material. The spatial resolution of the measurements obtained using this system may be increased or decreased by embedding additional or fewer fibers in the panel during manufacturing. Second, we have recently obtained preliminary results for similar panels using short duration solid state laser pulses which travel through the fibers. Stress in the panels changes the propagation characteristics of the pulses, causing pulse reflection and attenuation. Current work involves interpreting the changes in these pulse properties to infer the distributed stress state and thus the structural integrity of the specimen.

The CHAIRMAN. Thank you. This has been a very interesting morning for me. Realizing that you are all not experts on every research project underway at your respective institutions, I wonder if each of you could just give us a few illustrations or examples of NSF-supported research at your institutions and what are some of the projects some of your colleagues are working on? Let us start with you, Dr. Diaz.

Dr. DIAZ. There are a variety of projects in the psychology department that NSF funds. Aside from the brain-growth work that I am doing, there is work done by Elizabeth Loftus on memory, and it has a great deal to do with the so-called sanctity of eyewitness testimony or just how you remember things. In the cognitive psychology area, there were a variety of projects going on involved in the way we approach and the way we think about certain topics. The process involved in decisionmaking, for instance. These are the types of projects in the psychology department.

In the medical community, virtually every one of the science labs has some NSF funding in one way or another. To go through a roster of that is beyond my keeping track of.

The CHAIRMAN. Dr. Knauss?

Dr. KNAUSS. The Graduate School of Oceanography does work in all aspects of oceanography, not just the physics of it the Gulf Stream, which I talked about, but also the geology and nature of the ocean floor, the chemistry of the ocean, and some of the biological aspects of the ocean. NSF provides support in all of these areas to our institution, in one way or another.

One of the most interesting problems that NSF has provided considerable support for is the issue of so-called sea-floor spreading; that is, the plates on the crust of the Earth, which are separated in the middle of the Atlantic Ocean and then are subducted down at the edges of the continents, such as the big trenches off Japan, the Aleutian Islands, and so forth. We now are Pretty well certain that this does indeed occur, and we have known it now for 20 or so years. The question is, What is the driving mechanism?

The sources of that are well beneath the surface of the Earth, down 20 or 30 miles or maybe more miles than that. We cannot get at that directly, of course, so we do it indirectly. We do it by looking at the rocks and the material that is brought up, volcanic material and otherwise, and then trying to piece back together again what the history of the mantle of the Earth beneath the crust had to be in order to provide the kind of processes we see. So we have gotten beyond the descriptive stage of what is sea-floor spreading, and we are now trying to learn what are the causes and the mechanisms that determine that.

The CHAIRMAN. Dr. Strong, let me change the subject just a little bit. In your research, did you seek funding from other sources before you went to NSF, or did you just go straight to NSF?

Dr. STRONG. Funding initially was from a general grant that our chemistry department had with the Du Pont Co. over a period of several years, and some of that money was used in supporting my research and the students. The college also has what it calls a professional development grants program, and I got small amounts of money from that. So these two, I guess, are the basis for developing the research far enough to think it was possible to apply to the National Science Foundation. I had had grants many years ago back in the sixties when I ran a high school development program, a national program, at the college, and this was supported almost entirely by National Science Foundation funds.

The CHAIRMAN. What I am getting at, Dr. Claus, in addition to what you said, Dr. Strong, I am trying to find out the relative importance of the National Science Foundation as a funding institution, relative to not just other Federal agencies such as NIH but also to outside sources in industry and nonprofit sector sources. You have indicated that you have had some help from the industry sources. Have you seen any indications that there are other sources that may be available?

Dr. CLAUS. Yes, I think in engineering there are. The problem that I have run into, in the work that I have done, is that usually those other sources want specific tasks accomplished.

The CHAIRMAN. In other words, they want you to accomplish a specific goal.

Dr. CLAUS. Exactly, especially industry. I have found personally it is difficult——

The CHAIRMAN. You seem to be saying applied research rather than basic research?

Dr. CLAUS. Exactly.

The CHAIRMAN. What I have found through the years is that NSF is crucial for basic research, as well as various applied research. Do you all agree on that?

Dr. KNAUSS. Absolutely. It is almost the only agency in the Federal Government that supports fundamental research with no strings attached.

Dr. DIAZ. My research, more than the others, does not have a direct link to industry. So the study is of the nature of the way the brain develops and will not be funded by anything other than NSF.

The CHAIRMAN. One of the great concerns the committee has is, of course, the relationship between you as researchers and prospective students. We are impressed that each NSF award also supports a number of graduates and possibly undergraduate assistants. But these are just statistics. How would you characterize the benefits or the drawbacks that students have resulting from your research?

Dr. KNAUSS. All I can say is that several of those slides I showed were the work of graduate students. I believe that almost without exception, every grant that we have in the Graduate School of Oceanography the National Science Foundation supports the minimum of one graduate student. We also are using our grant support to support in a specific way undergraduate students. Oceanography is not a field which many undergraduates are well aware of, except in the field of biological oceanography. It is difficult to get physicists and chemists to go into oceanography. One of the ways we can attract them is by providing undergraduate support for them in the summertime to come and learn about what an exciting field oceanography is. That often is by NSF support.

The CHAIRMAN. What has been your observation concerning undergraduate students? Do you find that they are better or less prepared in today's climate than they should be? Do you feel that the quality of graduate students is going down, or is it going up? That is kind of a dangerous question, I understand, but I would like to get an impression. Last year here, we had tremendous pressure on this committee to come up with a math and science bill. We did. It has not moved off the Senate calendar for well over a year now. The problem is, that one of our members would like to attach a 19-page civil rights amendment to it, and that has caused a lot of difficulty because the bill should be a math and science bill and not a hodge-podge of a lot of other, albeit important, issues.

Are graduate students diminishing in quality? Or is it just a matter of individual abilities?

Dr. KNAUSS. My view of it, running a graduate program now for almost 25 years, is that the best students we have now are at least as good as the best students we had 25 years ago. I think what has changed is that some of the students we get in the middle group are not as well trained as they should be. I think that at the upper end of the scale, there is no difference. But I think in the middle scale, there is where we are seeing that the undergraduate training and the high school training before that has not been as strong as it should have been.

The CHAIRMAN. Do you all agree with that?

Dr. STRONG. I think I would add one other observation. I deal with undergraduates, a number of whom go on to do graduate work at other institutions. I think what we have observed is that a few years ago, there were fewer students interested in science, particularly in going on, thinking about careers in science. Their interests were elsewhere. This has been changing more recently, with more students and particularly better students now again interested in the sciences. I guess what we would hope is that this can continue to be encouraged, that good students will find the sciences attractive.

The CHAIRMAN. I am glad to hear that because we are concerned about scientific manpower, as you know, in this committee and on other committees as well.

I am going to submit other questions to you, and I will keep the record open for others on the committee to submit questions to you. I have just one last question. If someone suggested that an easy way to reduce the deficit by $200 million would be to keep NSF funded at last year's levels, what would be your answer to their suggestion?

Dr. CLAUS. I do not have current NSF funding, so I would be very disappointed with that.

Dr. KNAUSS. Science is expensive, and it is very difficult even to adjust the cost of doing science to the cost of living. The equipment for doing science now is much more expensive than it was 20 years ago, and we need that kind of equipment. We need the new computers that are so important to our work. We need the very fancy complicated kinds of equipment, and then we need the people to help run that kind of equipment. So I think the cost of doing state-of-the-art science is more expensive now, and it is going up at an increasing rate. Just keeping the NSF budget at the cost-of-living increase means we lose ground.

Dr. DIAZ. There are some other issues as well. The benefits of science to the community at times are not as apparent as other investments, but it is just as important. Regardless of the specific discipline, most of the projects are going to generate other lines of research. They are going to generate other work, just besides getting people thinking about topics.

Major discoveries are not usually done on purpose. It is taking bits and pieces from a pool of knowledge. To cut into that is to cut into something that may be very beneficial to the society as a whole later on, and I would not like to see just cutting our options. We do not know what is going to come out of these things.

The CHAIRMAN. Thank you. I need to leave, and I will turn the remaining time over to my dear friend, Senator Pell, who takes a really active role in this area and who, of course, has played a significant role in the maintenance of the National Science Foundation. I have a lot of regard for him.

Let me just thank each of you for being here. This has been intellectually stimulating. I think it is a different approach to the reauthorization of NSF, and that is to just talk about a few of these projects and see just how valuable they are. I think each of you has added significantly to our knowledge through your research, and as a strong supporter of NSF, I feel real good about this hearing.

Senator Pell, I am so grateful to have you here. If you don't mind, I am going to turn the committee over to you. I have other questions, but I do not want to consume any more of your time. With that, I salute you and appreciate your being here.

Senator PELL. Thank you for your kind words, Mr. Chairman.

I would add that I am very sad I was not here for Dr. Knauss' presentation. We were marking up another bill in another committee at that moment.

I went through the material, the photographs, and I was struck by one thing. Apparently, the Gulf Stream is not only offshore but it requires deeper water for it to exist. What is the reason for the Gulf Stream existing at all? What makes the Gulf Stream? Why is it that it does not come closer to the shoreline.

Dr. KNAUSS. That is a very difficult question to answer very quickly. The Gulf Stream, in the simplest sense, is controlled by the winds and the rotation of the Earth. You need both to have a strong Gulf Stream. You have to have the westerly winds at our mid-latitudes, and the trade winds at the southern latitudes, and you have to have the Earth rotate the way it does. If the Earth were rotating in the opposite direction, for example, you would have a strong Canary Current off the coast of Europe, rather than a strong Gulf Stream. You would have a very diffuse Gulf Stream, for example. So the rotation of the Earth gives it that narrow, sharp intensity, and it is the wind itself which combines to drive the water in that circular motion in the Atlantic Ocean.

There is a comparable kind of current in the Pacific Ocean, called the Japanese Current, which is like the Gulf Stream. It is only a little bit different, because the shape of the Pacific is different from the shape of the Atlantic.

Senator PELL. What would be the reason for its not being close to the shoreline?

Dr. KNAUSS. The Gulf Stream is close to the shore. It comes up the coast of Florida to about Cape Hatteras, and then it begins to leave the shore. It begins to go across the Atlantic Ocean. You can imagine these major ocean currents as being connected, almost as a circle as you go around the Atlantic Ocean. It goes across the Atlantic Ocean to about Newfoundland, where it is the Gulf Stream, and then it is given another name, the West Atlantic Drift, and then the water comes down south off the coast of Europe, the Canary Current, and then they call it the North Equatorial Current, and it comes back across. You can think of the whole motion of the ocean as being circular, if you will.

But the Gulf Stream is very special because of the Earth's rotational effect. It takes that broad current and makes it very narrow and very intense.

Senator PELL. In connection with the vessels that we have for oceanographic research purposes, I think that there are less than 15 or so in the United States. What is the status of that fleet, and particularly the *Endeavor* that you have in Rhode Island?

Dr. KNAUSS. You are right. We have about 15 research vessels that are supported by the National Science Foundation, primarily, and also in part by the Office of Naval Research. It is the so-called academic fleet, the UNOL's, the University National Ocean Laboratory fleet. Those are all modern ships. They are not like the old ships we had before, which were World War II surplus ships. They are all built for the purpose of being research vessels.

The oldest of these is about 22 years old: 1962. The general feeling among my colleagues is that it is not going to be time for what you could call a "second generation" research vessel, it is going to be time to begin to think about the "third generation" research vessels, because 30 years is about as old as you want for a research vessel, and it takes us about 7 or 8 years, once we decide to do something, to begin to have ships coming down the line. So now is the time to begin making plans for the next generation of research vessels, because the oldest of those vessels was built in 1962.

Ours is one of the newer ones, the RV *Endeavor*, and we are very fortunate with it. She runs very well, everything works, we have had our shakedown problems with it as you have with all new research vessels, but she is now generally thought of as one of the most efficient and one of the most successful ships in the fleet.

Senator PELL. Does NOAA itself have any research vessels of their own, under the U.S. Government flag?

Dr. KNAUSS. Yes.

Senator PELL. How many would they have?

Dr. KNAUSS. The U.S. Navy has research vessels, and NOAA has research vessels, both for general purpose research as well as survey work and with fisheries research.

Senator PELL. But that would not be included in the 15?

Dr. KNAUSS. That would not be included in the 15 that I referred to, sir.

Senator PELL. So we have a total oceanographic fleet of about 40 or 50?

Dr. KNAUSS. I do not know the exact answer, but I would say at least 30.

Senator PELL. Would you, in your view, believe that we are the leading oceanographic research Nation in the world? Is there any other nation with as large a fleet or working as hard in it as we are?

Dr. KNAUSS. The Russians have a much larger fleet. They clearly have many more research vessels. They do much more work than we do, and they have very bright people, but the system is impossible. Because of that, in spite of the fact that they have more ships and a lot of bright people, we still are the major research nation in the world, as far as oceanography is concerned.

Senator PELL. Do we have any exchange programs or relationships with our Soviet opposite numbers?

Dr. KNAUSS. We have had in the past, of course, and, to the best of my knowledge, there are no official bilateral programs presently in place with the Soviets. There certainly are still a fair number of informal contacts that continue, the exchange of reprints and this sort of thing, but I am not aware of any joint programs for the Soviets at this time in oceanography. I might be wrong, but I think that is the case.

Senator PELL. Were there joint programs before Afghanistan, or is this one of the casualties of the cool relations between the Soviet Union and us?

Dr. KNAUSS. Afghanistan was certainly a major reason for it, yes. For example, the deep sea drilling program, which has the *Glomar Challenger* and now, more recently, the *Fedco 471*, which does the drilling all over the world's oceans is a joint program operated by the National Science Foundation, which had as well as the United States, the Soviet Union, the United Kingdom, France, and the Federal Republic of Germany, and Japan. As of a few years ago, the Russians were out. That was, I believe, specifically related to Afghanistan.

Senator PELL. Thank you very much, Dean Knauss. I look forward, when the record is transcribed, to having a chance to read what I missed by not being here. I appreciate very much your coming down.

Dr. Diaz, in connection with your presentation on brain growth research, I was curious: were you touching there on the physical aspects of it, or were you touching at all on the psychological aspects as to the development of the brain?

Dr. DIAZ. I believe that the expression of behavior is in fact the brain functioning. So, for me, I do not make a distinction between physiological and psychological in that sense. Behavior is a physiological event. I was referring to both. The first thing to do is to determine what are the deficits, and then the next step is to say, What difference does it make? So a person has a 10-percent brain deficit; can you notice it, will it affect their lives so that you should avoid it? That is the permanency and the exact nature of brain deficits that occur early is what we are hoping to continue to investigate.

Senator PELL. If the deficit occurs in the left lobe as opposed to the right lobe, or vice versa, would that have a different reaction on the person's behavior and thought processes?

Dr. DIAZ. That would not happen. There has been much ado about left-brain/right-brain differences. The fact remains that we do deal with the whole brain. Except in unusual cases, both hemispheres are receiving information, and it is unusual if you have a trauma that would center on one and not the other, not unless it is an injury of some sort.

Senator PELL. Do you believe there is any difference between the left brain and the right brain?

Dr. DIAZ. I think the way the cerebral cortex is organized and the specializations that occur have been documented. That is something that cannot be denied.

Senator PELL. In other words, one is more creative and the other is more mundane?

Dr. DIAZ. I am not sure I would exactly agree with that.

Senator PELL. How would you characterize the differences?

Dr. DIAZ. I would characterize the difference in the sense that there is so much processing that has to occur, so much higher-order processing that has to occur, that at that particular level, redundancy is not going to be the most efficient way for an organism——

Senator PELL. What?

Dr. DIAZ. Redundancy: to have it bilaterally represented. It is not the most efficient way of processing that information. Not everyone is as lateralized as the popular literature would have you believe, and there are people who do in fact have many functions that are bilaterally represented. The capability of recovery of certain functions is possible.

Senator PELL. But that was not my question. My question was, do you, Dr. Diaz, feel that there is any difference between the left lobe and the right lobe?

Dr. DIAZ. Yes.

Senator PELL. What are those differences?

Dr. DIAZ. The difference is in not the exclusive lateralization of function but in areas taking primary responsibility for certain functions. So certain areas will take the lion's share in performing certain tasks, but that is not to say that it is exclusive, it is not to say that we are two-brained. Under normal circumstances, there is communication between the two.

Senator PELL. I agree with you, creative versus mundane is not too good. How would you describe the differences?

Dr. DIAZ. I would not characterize one hemisphere over the other in those terms. You could just go down the list and describe what functions may be lateralized on one side and what may not be on the other.

[Additional material supplied for the record follows:]

ADDITIONAL STATEMENTS FOR THE RECORD

Dr. Anna J. Harrison, President, American Association for the Advancement of Science

Dr. Warren D. Niederhauser, President, American Chemical Society

Drs. Robert P. Williams, Harlyn O. Halvorson, and Moselio Schaechter on behalf of the American Society for Microbiology

Dr. Roberta Balstad Miller, Executive Director, Consortium of Social Science Associations

Statement by

ANNA J. HARRISON

President

American Association for the Advancement of Science

on

The Fiscal Year 1985 NSF Budget Authorization Request

Submitted for the Record

Committee on Labor and Human Resources

United States Senate

April 6, 1984

[illegible]na J. Harrison: Professor Emeritus Chemistry, Mount Holyoke College

Degrees:
- Doctor of Philosophy (1940), University of Missouri, Physical Chemistry
- 14 Honorary Doctor of Science Degrees

Academic Appointments:
- Distinguished Visiting Professor, U.S. Naval Academy, 1980
- Department of Chemistry, Mount Holyoke College, 1947-1979
- USAID Banaras Hindu University, India, Summer 1968
- Sophie Newcomb College, Tulane University, 1940-1945
- Rural school teaching, Missouri, 1933-1935

Research Appointments:
- Collection and Detection of Toxic Smokes, Office of Scientific Research and Development Project at University of Missouri, 1943-1944
- Infrared Absorption of Quartz, Corning Glass Works, Summer 1945
- Research in Flash Photolysis, Cambridge University, 1952-1953
- Photolysis in the Far Ultraviolet, National Research Council, Canada, 1959-1960

Publications:
- Journal of the American Chemical Society, Journal of Physical Chemistry, Review of Scientific Instruments, Proceedings of the Royal Society, Journal of the American Ceramic Society, Journal of Chemical Physics, Journal of Chemical Education, Encyclopaedia Britannica, Science, Journal of Science, Technology and Human Values

Professional Service:
- President, American Association for the Advancement of Science, 1983-1984
- Convener and Cochairman AAAS-UN Panel of Experts, Science, Technology and Women, 12-16 September 1983
- Editorial Board, AAAS publication, Science 80, 1979-1982
- Phi Beta Kappa Visiting Scholar, 1979-1980
- President, American Chemical Society, 1978
- US National Committee, International Union of Pure and Applied Chemistry, 1978-1981
- Editorial Board, Journal of College Science Teaching, 1974-1978
- Editorial Board, Chemical and Engineering News, 1976-1978
- Chairman, Division of Chemical Education, American Chemical Society, 1971
- National Science Board, 1972-1978
- Board of Publication, Journal of Chemical Education, 1959-1966, 1970-1973, Chairman, 1964-1965

Honors:
- American Chemical Society Award in Chemical Education, 1982
- James Flack Norris Award for Outstanding Achievement in Teaching of Chemistry, Northeastern Section of American Chemical Society, 1977
- Manufacturing Chemists Association Award in College Chemistry Teaching, 1969
- Petroleum Research Fund International Grant, American Chemical Society Petroleum Research Fund, 1959-1960
- Sarah Berliner Fellowship, American Association of University Women, 1952-1953
- Frank Forest Award, American Ceramic Society, 1949

BEST COPY AV[illegible]

I am Anna Harrison, president of the American Association for the Advancement of Science. First, a few words about AAAS. AAAS has a membership of approximately 135 thousand. This encompasses a wide array of individuals professionally involved in the investigation of physical, chemical, biological, behavioral, social, political and economic phenomena and the use of physical, chemical, biological, behavioral, social, political and economic phenomena to solve problems and resolve issues.

The unique potential of AAAS is its capacity to facilitate communication among the great multiplicity of scientific, engineering and related professional societies; to provide mechanisms to address issues of concern to these organizations and to provide public forums to address issues which involve the relation of science, engineering and technology to society. The activities of AAAS reflect its strong commitment to the use of science, engineering and technology to enhance the quality of life of this and succeeding generations.

We have a vital interest in the level and the rate of growth of federal support for investigations in mathematics, science and engineering and for education in mathematics, science and engineering at all levels.

The $1.5 billion proposed FY 1985 NSF budget is very reassuring. In a period of alarming national deficits, this 14% increase over the $1.3 billion of the FY 1984 current plan demonstrates the commitment of the current administration to the support of mathematics, science and engineering research through the National Science Foundation. The overall increase in NSF's R&D budget is again one of the largest R&D increases among the federal agencies.

To assess the NSF budget, from the standpoint of AAAS, requires an inspection of both the magnitude and the rate of growth of proposed obligations by activity and subactivity. The attached table is essentially the budget summary table given on page 32 in the green booklet, National Science Foundation Budget Summary Fiscal Year 1985, with one column deleted and two columns added. The column deleted is the incremental difference between FY 1984 current plan and the FY 1985 proposed budget. The added columns are FY 1980 (actual) and the percent changes from FY 1980 to FY 1985 corrected for inflation. There have been a few corrections of minor magnitudes in some of the figures in the NSF Budget Summary FY 1985 table as published in the green booklet.

My focus for the moment will be upon the first four directorates. These four directorates account for $1.2 billion of the FY 1985 budget and I shall refer to these directorates as the four R&D directorates. Two other directorates will be considered separately.

The FY 1985 proposed budget for each of the four R&D directorates has, a very significant increase compared to the FY 1984 current plan, ranging from 12.6% for Biological, Behavioral and Social Science to 21.6% for Engineering. All subactivities within the four directorates show significant real growth, ranging from 8.2% to 24.3% in current dollars. The pattern of increases for FY 1985 is very similar to that for FY 1984, although slightly less in magnitude.

An inspection of the subactivities of these four R&D directorates indicate that three of the four deal primarily, but not exclusively, with investigations in mathematics, investigations of physical and chemical phenomena, and investigations in the use of mathematics and physical phenomena in solving problems. These three directorates are: Mathematical and Physical Sciences, Engineering; and Astronomical, Atmospheric, Earth and Ocean Sciences, with a total proposed budget of $0.94 billion. NSF supported investigations of biological, behavioral, social, political and economic phenomena, and the use of biological, behavioral, social, political and economic phenomena in solving problems and resolving issues are primarily, but not entirely, grouped together in the fourth directorate, Biological, Behavioral, and Social Sciences with a proposed budget of $0.25 billion.

A somewhat different pattern of growth emerges if the proposed FY 1985 budget is compared with the FY 1980 (actual) budget. By directorates, the percent changes from FY 1980 to FY 1985 (corrected for inflation) range from a decrease of 1.2% for Biological, Behavioral and Social Sciences to an increase of 39.2% for Engineering. By subactivity, percent changes range from a decrease of $48.7% for Social and Economic Sciences to an increase of 71.5% for Electrical, Computer and Systems Engineering. For the five-year period, the funding of two other subactivities also decreased. The decreases are 2.2% for Behavioral and Neural Sciences and 14.2% for Information Science and Technology.

I raise the question of the adequacy of the national investment in the investigation of biological, behavioral, social, political and economic phenomena and the investigation of the use of biological, behavioral, social, political and economic phenomena in solving problems and resolving issues. This is a very fundamental question. The answer is a value judgment and can only be made for the nation by the public through the surrogates of the public — those elected by the public and those appointed by those elected.

To explore the question involves a consideration of the ways scientific and engineering investigations serve the public good. Science, the investigation of phenomena, generates a body of scientific knowledge consisting of a data base, an array of methodologies and an array of concepts. Engineering, the investigation of how to solve problems, generates a body of engineering knowledge consisting of a data base, an array of methodologies and an array of concepts. The combined body of knowledge serves society in at least three significant ways.

1) It enhances our capacities to carry on further investigations of phenomena and further investigations of how to solve problems.

2) It is in part the basis of our perception of our physical, biological, social, political and economic environment, in part the basis of our perception of ourselves and our relations with others and in part the basis of our perception of our capabilities to carry on further investigations and to solve problems. And,

3) it fosters technological innovation, supports technology (the production and delivery of goods and services) and supports the effective use of the products of technology.

Approximately three quarters of the proposed FY 1985 budget for the four R&D directorates is for the support of investigations in mathematics, investigations of physical and chemical phenomena and investigations of how to solve problems (engineering) using physical phenomena.

The scientific, engineering and technological community cannot solve societal issues. Only society can solve societal issues. Scientists and engineers can identify issues, assess the nature and magnitude of the issues, identify areas requiring further investigations, propose technological options, assess the probable positive impacts and the probable negative impacts of each option (including the option to do nothing) on society. Societal issues have to do with the quality of life and decisions having to do with the quality of life are prerogative of the public and the surrogates of the public. Once the decision is made to implement a particular option, scientists and engineers have a great deal to do with the implementation of that option.

I consider the selective use of technology to enhance the quality of life of this and succeeding generations to be one of one most significant societal issues. Concerns related to the quality of life include national defense and national economic growth but are in no sense limited to those two very significant issues.

Every technological change, brought about by either transfer or innovation, has a negative impact on society regardless of how great the positive impact of that technological change upon society. There is no direct proof for this statement. For some years I have challenged

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audiences to cite examples of technological change for which the statement is not true. I still know of no example for which it is not true. The subset of society that derives the benefits may not be the subset that bears the burdens. The time frame within which the benefits become evident may be quite different from the time frame within which the burdens become evident. The nature and magnitude of the benefits may be quite different from the nature and the magnitude of the burdens. The goal is, of course, to selectively use technology to enhance the quality of life and more equably disperse the benefits and burdens of technological change.

We have yet to develop generally accepted quality of life indicators and the practice of using economic indicators is at best a very inadequate substitute - particularly if the data base cannot be disaggregated to monitor identifiable subsets of society in successive time intervals.

The sweet/bitter consequence of technological change is not a unique characteristic of technological change. It is instead a characteristic of change - all social, political and economic change. The goal of technological transfer and technological innovation is change.

Traditionally, engineering has been the investigation of problem solving through the utilization of physical and chemical phenomena. The subactivities of the NSF FY 1985 budget of the Engineering Directorate encompass this type of engineering. Today, engineering also encompasses the investigation of problem solving utilizing biological phenomena and terms such as bioengineering and genetic engineering have become a part of our language.

Parallel approaches to the solution of problems and the resolution of societal issues involve and utilize behavioral, social, political and economic phenomena. Societal issues such as abused children are only very remotely related to physical phenomena and the resolution of such issues is not to be found in the utilization of physical phenomena. Even the resolution of issues, such as waste disposal, which do involve physical, chemical and biological phenomena are dependent upon the resolution of a host of behavioral, social economic and political problems as well as the development of technological options involving physical, chemical and biological phenomena. The approach to the resolution of international conflict through negotiation is highly dependent upon the knowledge and understanding of the social, economic and political structures and priorities of the nations involved and an understanding of the relation of proposed solutions to those structures and priorities.

To assess the adequacy of the federal support for basic research in the biological, behavioral and social sciences goes far beyond a consideration of the NSF budget. Under the proposed FY 1985 budget, NSF would support less than 17% of the total federal basic research effort. We are all familiar with the support of investigation of biological phenomena in departments such as Agriculture and Health and Human Services. Other sources of support for investigations of behavioral, social, political and economic phenomena are not as visible.

I am a physical chemist and am well aware of and very proud of our Nation's tremendous capabilities to investigate physical and chemical phenomena, to use physical and chemical phenomena to develop technological options and to use the data base, the methodologies and the concepts of the physical sciences and of engineering to investigate biological phenomena and to investigate extremely large and complex systems such as the oceans. The capacity of this Nation to plan and undoubtedly build and effectively use the long base line array of radio telescopes is an elegant display of past accomplishments and current capabilities. It is exactly this pride in the past and this confidence in our current capabilities that leads me to be so concerned that limited knowledge and understanding of behavioral, social, political and economic phenomena could inhibit the resolution of societal issues and the enhancement of the quality of life.

The AAAS Board recognizes the synergistic nature of science and engineering and also the growing unity of science and engineering, even though the disciplines of science and the disciplines of engineering are rapidly proliferating. The AAAS Board is in the process of taking to the AAAS Council a recommendation for a change in AAAS goals to recognize and facilitate the growing unity of science and engineering and the AAAS would support the investigation of mechanisms to bring science and engineering closer together in federal agencies.

The Scientific, Technological and International Directorate (STIA) is quite different in structure and foundation from the four R&D directorates. One of its more interesting features is that it coordinates a number of activities which are carried out by the R&D directorates and funded through the R&D directorates in the proposed FY 1985 budget to the extent of $80.7 million. These special activities include the NSF Small Business Innovation Research Program, the Indo-US Science and Technology Initiative, Research Opportunities for Women, Presidential Young Investigators Research Awards and Support for Predominantly Undergraduate Institutions. This approach assures the standards of excellence and processes of peer review characteristic of NSF R&D directorates. It is too early to assess the success of this approach. In principle, I find the approach attractive and suspect that the degree of success will be closely related to the quality of oversight within STIA and also the level of oversight of the NSF Director. It will require diligence to assure that these activities do not become diffused and possibly distorted or diverted by the R&D directorates.

Another subactivity of STIA is policy research and analysis. I believe that this should involve two types of research and I am not confident that it does. The two types of research are: 1) research on science policy as a discipline and 2) research and analysis as a basis of formulating agency or government policies dealing with science, technology and natural resources. Both types of research and analysis are important but they are different. I believe that it is important to recognize and maintain the difference. In the first case, the investigator is a student of science policy and presumably has no vested interest in the outcome of the analysis. In the second case, the investigator becomes a participant in the formation of policy dealing with science, technology and natural resources and may impose personal value judgment on the outcome of the analysis. There is ample evidence of research of the second kind. It is not clear how much support is given to investigations of the first type -

the research essential to the development of the discipline of science policy. The first type of research parallels the type of research essential to the development of the discipline of chemistry.

STIA also has the responsibility to conduct surveys and maintain the science resource data base. AAAS places a high value on the potential usefulness of this data base for research, including research to assess the entry of women, minorities and the physically handicapped into scientific and engineering careers and the movement of women, minorities and the physically handicapped up the career ladders of scientific and engineering professions. We recommend oversight to insure that the data base for scientific and engineering personnel can be disaggregated to yield this information.

The FY 1985 budget for the Science and Engineering Education Directorate is stated in terms of two subactivities, Graduate Research Fellowships and Precollege Science and Mathematics Education.

A modest increase in funding for fellowships provides for a modest increase in the number of fellowships and in the stipends of the fellowships. This well-established program remains intact.

The proposed FY 1985 budget is 22% lower than the funds made available under the FY 1984 current plan for precollege science and mathematics education.

I find this action to be absolutely astounding. Even assuming that Congress will intervene and increase the funding for precollege education, the Science and Engineering Education Directorate will have been denied the opportunity to design and to present a coherent program. The course taken by the Directorate seems to be the presentation of a very nebulous array of programs that far exceeds the level of funding made available in the proposed budget. There will undoubtedly be proposals and some meritorious proposals will be funded, but there will be no identifiable thrust by the National Science Foundation. We need leadership from the National Science Foundation in precollege education and in my opinion, we do not have it.

I serve on the Education Commission of the States Task Force on Education for Economic Growth and am well aware of the initiatives being taken in many of the states largely as a consequence of the leadership of the governors of those states. The progress being made is impressive. These initiatives for the most part address the environment within which education takes place – the number of required courses, pay for teachers, the availability of equipment, the length of the school day, the length of t[illegible]ool year, discipline, etc. They do not tend to address the nature [illegible]ucational experience itself. To address the nature of the educa[illegible]erience in mathematics and science for all students at the precollege level is, to me, uniquely appropriate to the National Science Foundation. In the smorgasbord of programs mentioned in the supporting budget documents, there are opportunit[illegible] to address the nature of the educational experience but there is no thrust. The value of the whole should exceed the value of the sum of the parts.

The place of the NSF in precollege education must be addressed by Congress during this session of Congress. The National Science Board (NSB) Commission on Pre-College education first met in July 1982; it transmitted its report to Congress, and to the NSB in September 1983.

For another year to go by without vigorous action will be negate the responsibility ~~of Congress~~ and the NSB.

The remainder of this statement will consist of brief comments on a variety of general issues.

International Activities. AAAS interests, goals and practices are entirely consistent with the National Science Board Statement on Science in the International Setting (September 1982) and it is not necessary to restate those principles here. (A copy of the Board statement is attached.). We urge a stable rate of growth in the support of programs consistent with the NSB statement. One of the AAAS activities is to serve as the secretariat for the Consortium of AAAS Affiliated Scientific Societies for International Programs. The Consortium provides a communication system for about 70 scientific and engineering societies with international programs.

Access to computer facilities and electronic information systems. AAAS recognizes the essential nature of ready access to appropriate computer facilities and to scientific and engineering information for all scientists and engineers in all scientific and engineering disciplines and we urge NSF to assist scientists and engineers to discover the potential of computer methodologies appropriate to their research and to facilitate access to computer facilities and information systems through networking and siting appropriate computers at strategic locations. In particular, we make the plea that scientists and engineers, in subdisciplines that have yet to embrace wholeheartedly computer methodologies, be involved in the strategic planning for the installation of computers and the development of networks.

We recognize that computer generations follow computer generations and that only long-term planning can insure the availability of the latest generation of computer systems. Access and utilization to these advanced computers and information systems is revolutionalizing the ways in which scientific and engineering investigations are carried out. This is an issue that goes far beyond the capabilities of any one agency to address in an adequate fashion for the nation. It calls for strategic thinking in terms of what are appropriate national actions — governmental and private — and how the support shall be provided.

<u>Administrative Issues</u>. (Personal comments) The scientific and engineering community was shaken by the circumstances under which some of the assistant directors at NSF were asked to leave in late 1982. At the time, I was assured that I would be reassured when the identity of the replacements became known. The sad fact is that five of the directorates discussed in this statement are still operating under the leadership of acting assistant directors. Equally troubling is that several of these acting assistant directors continue to fulfill as well the responsibilities of the positions they held before the appointment to an acting assistant director. This is not reassuring to the scientific and engineering community.

Second Comment. During the last years that I served on the National Science Board, I chaired the Program Committee of the Board. On the basis of that experience, I strongly support the recommendation of the Chairman of the National Science Board to amend the NSF Act to allow the Board to delegate the Director approval authority for grants that do not exceed \$6 million in total or \$1.5 million in any one year. Even in 1977 and 1975

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the [illegible] of 12 and 30.5 million excessively focused the attention of [illegible] on Big Science and it was essentially impossible to develop an in [illegible] of the activities of NSF in the support of small science.

The NSF Budget Process. (Personal comment) I regret the pattern of [illegible] that pits a commitment to science and engineering education against a commitment to research in science and engineering. Many of us discover that we have met the enemy and it is us. We are committed to both. This conflict is accentuated by the frequently reoccurring pattern of a very low proposed budget for science and engineering education being raised by Congress without increasing the total NSF budget. The net result is "that funds are transferred from research to education." I understand the game that is being played but I wonder if those who play it understand how divisive it is to the scientific and engineering community. Research and education are synergistic and they should be perceived to be synergistic.

General Comment. (Personal comment) The NSF FY 1985 proposed budget is a strong budget and any criticisms that I have made and questions that I have raised are derived from my confidence that NSF is a vital foundation and that it is fully capable of providing an even higher level of leadership and service to the scientific and engineering community and to the Nation as a whole.

American Chemical Society

OFFICE OF THE PRESIDENT

Warren D. Niederhauser
President-Elect, 1983
President, 1984
Immediate Past President, 1985

1155 Sixteenth Street, N.W.
Washington, D.C. [illegible]
Phone [illegible]

April 11, 1984

The Honorable Orrin G. Hatch
Chairman
Committee on Labor and Human Resources
United States Senate
Washington, D.C. 20510

Dear Senator Hatch:

As the world's largest scientific society dedicated to a single discipline, the American Chemical Society offers the following observations on the Administration request for the National Science Foundation for FY 1985. Our comments focus on the proposed funding of chemistry research, facilities, instrumentation, and science education, as well as on the general state of the chemical sciences, and how the federal government can continue to advance it. We hope your Committee will find these comments helpful in your deliberations on the NSF authorization.

The importance of chemistry to the national well-being must be fully recognized and exploited. Chemistry impinges on virtually every aspect of our daily lives, and is fundamental to such vitally important scientific endeavors as petrochemical catalysis, new energy processes, high performance plastics, advances in medical science and biomaterials, and new electronic materials and devices. In interdisciplinary science and technology, chemistry is critically important in understanding synthesis and properties of metals, ceramics, and polymers; surface and interfacial phenomena relative to adhesion, wear, corrosion, and biocompatibility; electronic, optical and magnetic behavior of materials; and development of medical devices and materials, to name just a few.

While the Society is heartened to see that the NSF FY 1985 budget for chemistry is slated for a healthy increase, the opportunities before us in the field could justify a far larger increase than what is proposed. Beginning with an inadequate base, NSF funding for chemistry over the last decade barely kept up with inflation. At the same time, the cost of doing research rose much faster than inflation, because of the increasing sophistication of research instrumentation and the increased cost of the support structure needed to carry out high quality research. As a result, many excellent research projects were funded inadequately, and many more could not be supported at all. Meanwhile, the support structure for both research and chemical education continued to deteriorate due to lack of resources.

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We must insure that promising research directions are fully explored, guarantee that the human resources needed by our industries are forthcoming, and maintain the research and education support structure necessary to a healthy discipline. In this regard, our major points on the FY 1985 authorization can be summarized as follows:

- In general, ACS is pleased with the proposed NSF budget request for chemistry for FY 1985, although greatly increased support could easily be made use of.
- ACS favors the planned increase in NSF support for instrumentation purchases, and also recommends that funds be available for operation and maintenance.
- The government should study the problem of aging facilities and what impact this has on U.S. science.
- ACS favors the planned NSF effort in supercomputers, but stresses that the commitment must be a long-term, sustained one.
- ACS applauds the efforts of NSF in developing special programs to encourage young investigators, women, and minority students.
- ACS favors an increased NSF role in precollege science and mathematics education, but believes more support is needed than has been requested.
- In general, state governments and the private sector need to address the problems of education and aging facilities, since the federal government cannot solve these problems by itself.

The enclosed discussion paper goes into all of these points in greater detail.

The American Chemical Society is an individual membership organization of more than 130,000 chemists and chemical engineers reflecting a broad spectrum of academic, governmental and industrial pursuits. The Society appreciates this opportunity to submit its views on the role of the National Science Foundation and the state of the chemical enterprise.

Sincerely,

Warren Niederhauser

Warren Niederhauser

Enclosure

I. THE VITALITY OF THE SCIENCE OF CHEMISTRY

"This is a time of special opportunity for intellectual advance in chemistry. It derives from our developing ability to probe the elemental steps of chemical change and, at the same time, to deal with extreme molecular complexity. They account for the recent acceleration of progress that gives chemistry unusual promise for high return from additional resources."

These words, from the panel of the National Academy of Sciences which recently briefed the Office of Science and Technology Policy on selected opportunities for research in chemistry, capture the vitality of the chemical sciences. The panel noted three promising research frontiers in which immediate funding increases would provide dividends: (1) Understanding Chemical Reactivity; (2) Understanding Chemical Catalysis; and (3) The Chemistry of Life Processes. A total of $75 million in real growth has been recommended for FY 1985 as appropriate to take advantage of these opportunities. About $50 million of this growth would be in NSF funding.

The timing of the OSTP research briefing (October 13, 1983) was rather late in the cycle for the NSF budget formulation. We hope that is the reason for the much smaller increment that appears in the budget of the NSF Chemistry Division which rose $12 million, about $7 million above inflation. Nevertheless, ACS is cognizant of the current political realities, and therefore we appreciate the modest but real growth in the FY 1985 budget of the NSF Chemistry Division budget. We mention the NAS recommendations to indicate that much higher funding levels for chemistry would not be wasted. The ACS recommends that the NSF designate increasing funding for chemistry research as a major initiative in its formulation of the FY 1986 budget.

II. MAINTAINING THE PHYSICAL INFRASTRUCTURE FOR SCIENTIFIC RESEARCH

A. Instrumentation

The ability of our institutions of higher education to perform research and educate students is increasingly dependent upon access to up-to-date instrumentation. In research such instrumentation is needed for both observation of new phenomena and testing of theoretical models.

Recent surveys, including one conducted by the ACS Committee on Science, have shown that our graduate and undergraduate departments of chemistry and chemical engineering have fallen behind in this area. This problem is aggravated by the increasing difficulty in obtaining matching funds. It is estimated that substantial expenditures will be needed in order to provide adequate instrumentation to our colleges and universities. Both private and governmental sources must be tapped if the problem is to be effectively addressed.

The ACS commends the NSF for the steps the Foundation has taken to increase support for scientific instrumentation. The Society urges the NSF to continue its effort to fund instrumentation purchases, and also favors support for maintenance of the instruments, once acquired. At the same time, we hope the Foundation will assist in gathering and disseminating information about alternative financing mechanisms which academic institutions could use for purchasing instruments. In short, we strongly urge Congress and the Foundation to continue to pay special attention to this major weakness in our nation's ability to perform academic research.

B. Facilities

There are signs that our physical facilities for scientific research and education are deteriorating due to age, and that schools have difficulties finding the capital for building and restoration of facilities. We should not ignore what may well be a great problem ahead. However, the magnitude and nature of the problem are not well understood at this time.

The ACS believes that the federal government should sponsor studies to develop an understanding of the problem. It should be recognized, however, that if the magnitude of the problem is great, the federal government cannot be expected to solve it by itself. State governments and the private sector must also bear part of the responsibility for developing creative and innovative solutions.

C. Supercomputers

The ACS supports the new NSF effort to make supercomputing facilities available to its grantees. The plans highlighted by the Director of NSF represent a good beginning. ACS is most concerned about ensuring that the effort is backed by a continuing commitment to increase access to supercomputers for academic research scientists and engineers. It is crucial for the National Science Foundation to take the lead in this area.

The Task Force on Large Scale Computing of the American Chemical Society has just completed a review of the kinds of problems in chemical research which can be studied within a reasonable amount of time only with the use of a supercomputer. The Task Force concluded that supercomputers will be important to chemistry in three broad areas: (1) numerical computations and simulation; (2) artificial intelligence including expert systems, pattern recognition, and symbolic manipulations; and (3) the development of and access to very large scientific data bases.

Also, the chemical science community seeks participation in some form of interdisciplinary network--not necessarily a single conventional network--which would permit terminal-to-terminal communication between individuals; ready access to numerical and bibliographic data bases; and access to calculating supercomputers. This network should allow fast efficient transfer of large quantities of information such as very long programs.

Projecting into the future, the Task Force also recognized that certain problems need to be addressed if our scientific enterprise is to proceed beyond the stage of piecemeal use of supercomputers. First is the need for users to agree upon some level of standardization in formats, descriptive vocabulary, symbol sets, and perhaps other aspects of computing. Second, a mechanism must be devised for identifying the needs for large data bases. Finally, an effective feedback structure is needed between supercomputer users, especially those at the scientific frontiers, and the industries designing and constructing the machine hardware. Except in the national defense sphere, interaction between users and designers seems to be virtually non-existent in the U.S.

III. NURTURING THE HUMAN CAPITAL FOR SCIENTIFIC RESEARCH

A. Support for Undergraduate Programs

The ACS applauds the Foundation's intent to increase support for predominantly undergraduate institutions through the research directorates. We understand the thrust of such support to be on research. However, a problem which is not addressed is that undergraduate departments of chemistry have nowhere to turn to at NSF for assistance in modernizing their laboratories. Since these departments are the source of all of our American candidates for graduate work in chemistry, federal programs should support instrumentation needs and the improvement of laboratory facilities for undergraduate teaching and research.

B. Research Support for New Investigators

It is appropriate that special programs be developed to encourage young investigators, women, and minority scientists, and to ensure them of the opportunity to try to become fully competitive when seeking research support. The ACS appreciates the great sensitivity shown by the NSF management in this regard.

We therefore support the Presidential Young Investigators Research Awards, and the Minority Research Initiation Program. We are also encouraged by the Foundation's decision to provide initial funding of $0.5 million for Research Opportunities for Women. We hope that this modest beginning will be followed by increased support in subsequent years.

The ACS and its Women Chemists Committee are very pleased that the Foundation doubled the FY 1984 funds for visiting professorships from $1.0 to $2.0 million, and is proposing to maintain this effort at the same level in FY 1985, to respond to the substantial number of exceptionally high quality proposals received.

In addition, we recommend that grants and contracts be made available for programs in science and mathematics geared to female and minority students in elementary and secondary schools, and in higher and continuing education, and that career reentry programs for women be reinstated, but modified to include reentry into academic careers, and not just industrial careers as in the past.

IV. SCIENCE EDUCATION

The American Chemical Society is pleased that the National Science Foundation will continue to play an important role in helping solve the nation's current problems in science and mathematics education. The re-establishment of the Office of Science and Engineering Education as a Directorate of the Foundation is applauded by the Society as a proper recognition of the importance of education in science, mathematics, and technology.

Again, it should be made clear to all concerned that the problem is one which the federal government cannot be expected to solve by itself. The government can and should provide leadership and attempt to instill a sense of the importance of the mission to upgrade the quality of science and math education. But state and local government, and the private sector, must become involved in order for these efforts to succeed.

While we are pleased that there appears to be a renewed federal commitment to precollege science and mathematics education, we believe that the federal effort remains inadequate. We continue to call for the development of a comprehensive focused policy that will provide long-term solutions to the many problems facing precollege science and mathematics. The ACS urges Congress to encourage NSF to obtain its necessary complement of knowledgeable staff for the Directorate of Science and Engineering Education.

The ACS believes that NSF should continue to play a major role in both initial and continuing education in science, mathematics, and engineering at all levels, from precollege to higher education, including graduate research. NSF should also be the leading agency to support the intellectual development of educational approaches, educational research and analysis, and the dissemination of information in science and mathematics education.

We recommend that NSF, as its highest priority, focus its efforts upon providing funds to help current teachers upgrade their subject matter competence; and to ensure that new teachers are sufficiently competent in subject matter knowledge to meet the standards necessary for state certification as full-time teachers in their discipline.

Hence, we are pleased with the stated intent of NSF to "broaden its support of in-service teacher training activities through local and regional workshops". While uncertain as to the extent of this "broadening", we trust that this implies an even greater level of support for this activity than found in the FY 1984 budget.

The Society believes that the teaching profession needs to be made more attractive than it is now, both in terms of remuneration and social prestige. Thus, we support the Presidential Awards Program. We also consider the Precollege Materials Development Research component of the budget to be essential.

We view with a great deal of interest the attempt of the Foundation to initiate partnerships with business, industry, and state and local governments. The utilization of resources from many organizations and institutions, including professional societies, should bring all groups concerned into closer working relationships with each other.

We were, of course, pleased to learn that the General Services Administration has just approved a charter for a new NSF advisory committee to the Science and Engineering Education Directorate. NSF should also establish external review panels composed of knowledgeable scientists, mathematicians, and engineers to critique directorate programs.

Finally, in the past, results--both positive and negative--of science education projects have not been shared widely enough. Therefore, we appreciate the intention of NSF to take a more active role to ensure wide dissemination of the results of projects.

In conclusion, ACS supports the efforts of the Directorate to improve the quality of precollege science and mathematics education in this country, and we stand ready to assist in this effort.

American Chemical Society
4/11/84

PUBLIC AND SCIENTIFIC AFFAIRS BOARD
AMERICAN SOCIETY FOR MICROBIOLOGY
1913 I STREET, N.W.
WASHINGTON, D.C. 20006
TELEPHONE: CODE 202, 833-9680

April 20, 1984

The Honorable Orrin G. Hatch
Chairman, Senate Committee on Labor and Human Resources
SD-428 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Chairman Hatch:

The Public and Scientific Affairs Board (PSAB) of the American Society for Microbiology (ASM) wishes to submit for your consideration the following comments on the Fiscal Year (FY) 1985 budget for the National Science Foundation (NSF).

The ASM is the largest single biological life science organization in the world with an active membership of over 31,000. Many of these individuals are engaged in biological research and a sizable number are recipients of awards administered by the NSF. A large number of areas are represented in their interests, including molecular genetics, photosynthesis, nitrogen fixation, regulation of gene expression, immunology, ecology and others. Our comments are directed primarily to funding for research and training conducted by the NSF Directorate for Biological, Behavioral and Social Sciences (BBS) and proposed amendments to the National Science Foundation Act of 1950.

The Administration has proposed a level of spending of about $204 million for the biological sciences in its FY 1985 budget request for the NSF. This represents an increase of approximately 12% over the projected FY 1984 expenditure. The PSAB supports this increase as a positive step toward fulfilling NSF's mission to support basic research in biology. We believe, however, that seen in a historical perspective, it is a relatively small step towards the restoration of the proper role of the NSF in the support of basic biological research.

The seriousness of the situation is illustrated by the fact that the budget for research in biology at the NSF has remained level between 1978 and 1983 in terms of 1972 constant dollars. This represents a considerable setback if you consider the extraordinary growth of biological research during that period. Scientific opportunities in biology have increased dramatically as a result of major breakthroughs in molecular genetic techniques. The BBS Directorate has had to make extremely difficult choices between funding even a moderate number of grants and awarding sufficient funds for the carrying out of research projects by investigators. It has had to steer a highly unsatisfactory middle course, as illustrated by the statistics for one of its components, the Physiology, Cellular and Molecular Biology Division (PCM). Between 1978 and 1983 the average award decreased by about 10% in 1972 constant dollars. Over the same interval successful grant applications decreased from about 40% to slightly over 30% of the total applications submitted. Thus, both the dollar value of successful grants <u>and</u> the proportion of successful grants decreased over this period.

In FY 1984 the BBS Directorate has begun to reverse this trend as the result of a 14% increase in the budget for biology. As stated in our letter to Congress last year, this will result in the beginning of the catch-up needed to restore the ability of the NSF to carry out its proper mission. We pointed out last year that a typical 1982 grant paid, at best, for one skilled technician, a few supplies, and no restoration or aquisition of equipment. The FY 1984 increments to the budget are being used, wisely in our opinion, to increase the value of successful grants. Thus, although the dollar value of grants increases by 14% in FY 1984, the number of funded grants increases negligibly from 1,491 to 1,505 for the PCM Division, an increase of only 14 grants. The figures speak of the very large infusion of funds that would be necessary to support a significant number of meritorious research grants at a level sufficient to carry out the work proposed.

While the support for research activities at NSF is at least headed in the right direction, the same cannot be said for the training budget. The FY 1985 proposed budget contains a 3.4% increase for Graduate Research Fellowships NSF-wide. Since the stipends would increase by 10%, this represents a decrease in the number of trainees. This lack of substantial increase in support of graduate and postgraduate training does not allow NSF to address the urgent need for qualified scientists in several important areas of biology. To use microbiology as an appropriate example, the number of new Ph.D.s in this field has remained constant at about 350 per year for the last 15 years. In the same time the demands in areas related to biotechnology have skyrocketed. A recent study by the National Academy of Sciences has shown that over a third of the annually produced Ph.D.s in immunology will be employed by industry. This figure represents the lowest estimate of <u>new</u> jobs created in this field. Similar numbers for other areas of microbiology indicate that the demand will become acute within a short time. In recent years it has been fashionable to conclude that the decreased need for academic personnel could result in an oversupply of Ph.D.s. Whatever the merit of this general perception, it is certainly off the mark in fields of science that have seen rapid academic and industrial development.[2] This country may eventually find itself at a competitive disadvantage with regard to personnel available to fill research positions. For this reason we urge you to consider a substantial supplement to the graduate training budget of the NSF. In the area of microbiology a 15% annual growth seems called for over the next five years. This would result in the doubling of the number of new Ph.D.s in this field supported by NSF.

We take this opportunity to comment on the amendments to the National Science Foundation Act of 1950 regarding the role of the NSF in engineering research as proposed by the House Committee on Science and Technology. As microbiologists we are involved in both basic research and its engineering applications. Biological processes, mostly employing microorganisms, play an increasing role in food production, disposal of wastes, fermentation, and mining of minerals, to name just a few areas. We view with concern the proposed changes because they do not take into account the selective nature of the interface between basic research and its engineering applications. As written the changes call for a pervasive marriage of the two in all activities of NSF. Such a union should not be imposed across-the-board because different areas of basic research ripen at different rates. The time and nature of their applications can often not be foreseen. As an example, the development of genetic engineering came on line through a technological route that could not be predicted as recently as twenty years ago. It is unlikely that this development would have been fostered by a congressional mandate. Thus, the merging of basic research and engineering

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should be based on specific considerations of the state of development of different fields of science. Inevitably, an imposed union will lead to competition for funds, since we have no assurance that monies for new functions will be added to the NSF budget. Should one activity win, it will be at the expense of the other, with consequences that are certain to be unproductive.

We would much prefer a continuation of the present system which deals with specific areas of applications of scientific findings. The NSF has been responsive to the need to foster technology transfer, as seen by the increase in the budget for its engineering directorate. It has demonstrated sensitivity and sophistication in the light of considerable external pressure for expedient but not necessarily appropriate solutions. It should be encouraged to continue along these lines.

We appreciate the opportunity to express our views and stand ready to provide additional information to support our comments.

Sincerely,

Robert P. Williams

Robert P. Williams, Ph.D.
President, American Society for Microbiology

Marilyn Q. Halvorson

Marilyn O. Halvorson, Ph.D.
Chairman, Public and Scientific Affairs Board

Moselio Schaechter

Moselio Schaechter, Ph.D.
Chairman, Committee on Genetic and Molecular Microbiology

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CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS

1755 MASSACHUSETTS AVENUE, N.W., SUITE 300, WASHINGTON, D.C. 20036 • (202) 234-5703

April 26, 1984

The Honorable Orrin G. Hatch
135 Russell Senate Office Bldg.
Washington, DC 20510

Dear Senator Hatch:

I am writing on behalf of the [illegible] social and behavioral scientists represented by the Consortium of Social Science Associations (COSSA) to urge the Senate Committee on Labor and Human Resources to increase by $5 million the FY 1985 authorization for the National Science Foundation's Biological and Behavioral Sciences Directorate (BBS). Of this $5 million increase, $3.6 million should be earmarked for research in the social and behavioral sciences and $1.4 million for research in information science.

The NSF social and behavioral science research programs were cut severely in FY 1981 and FY 1982 and are still being funded below their FY 1980 level in current dollars. In constant dollars, these programs are over 30% lower than they were five years ago. An increase in the FY 1985 authorization for these programs will provide needed support for research in such important areas as the economic impacts of deregulation, cognition and learning in science and math, change over time in family income and its effects on individuals and on the family, the study of the origins of human society, and communications and information technology.

Without an increase, support for the social and behavioral science programs at the Foundation will decline relative to other sciences. In FY 1984, the social and behavioral science programs are receiving 3.8% of all support for research and related activities. In FY 1985, they will only receive 3.6%.

The Labor and Human Resources Committee recognized the importance of social and behavioral science research in its report on the FY 1984 authorization for NSF when it stated:

> Evidence presented to the Committee, and in other forums and publications, suggests that the scientific potential and economic payoff of the social and behavioral sciences has been underestimated in recent years. Over the next several years the Foundation is requested to make every effort to provide resources for the social and behavioral science programs to enable them to meet their scientific potential.

COSSA urges the Committee to continue that recognition by increasing the funding for social, behavioral, and information science research in FY 1985 by $5 million.

Sincerely,

Roberta Balstad Miller
Executive Director

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association
American Psychological Association • American Sociological Association • American Statistical Association
Association of American Geographers • Association of American Law Schools • Linguistic Society of America

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CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS

1755 Massachusetts Avenue, N.W., Suite 300, Washington, D.C. 20036 • (202) 234-5703

TESTIMONY OF THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS (COSSA)

on the

FY 1985 AUTHORIZATION FOR THE NATIONAL SCIENCE FOUNDATION

Prepared for the

COMMITTEE ON LABOR AND HUMAN RESOURCES

UNITED STATES SENATE

The Honorable Orrin G. Hatch, Chairman

April 26, 1984

American Anthropological Association • American Economic Association • American Historical Association • American Political Science Association

American Psychological Association • American Sociological Association • American Statistical Association

Association of American Geographers • Association of American Law Schools • Linguistic Society of America

Mr. Chairman, the Consortium of Social Science Associations (COSSA) is pleased to have the opportunity to submit the following testimony on the FY 1985 authorization for the National Science Foundation (NSF) tot the Committee on Labor and Human Resources of the U.S. Senate. The Consortium represents 175,000 scientists across the full range of the social and behavioral science disciplines. A list of COSSA Members, Affiliates and Contributors is attached to this testimony.

COSSA is pleased that the budget request for the National Science Foundation includes an increase of 13.6% for FY 1985. Despite the severe constraints on the FY 1985 budget imposed by the size of the federal deficit, we believe that it is important to maintain the nation's investment in basic research. Without such continuing investment, the United States would become increasingly less able to compete with other nations economically, the quality of our science and inventiveness of our technology would decline, and we would weaken the flexibility of our economy in the future.

Not all NSF programs share in the recent increase in the NSF budget. Members of this Subcommittee do not need to be reminded of the major cuts in NSF budgets for the social and behavioral sciences in FY 1981 and FY 1982.

In FY 1985, the budgets of the social and behavioral science research programs in the Directorate for Biological, Behavioral, and Social Sciences (BBS) are scheduled for an overall budget increase of 10%, principally for support of the large scale data bases. This is an important and necessary emphasis. These data bases have suffered from the budget cuts over the past several years. They are expensive, yet they cannot be postponed until budgets are increased again. If a survey -- such as the National Election Study (NES), or the General Social Survey (GSS) -- cannot be conducted at the required time, its scientific value is impaired. The FY 1985 funding provided for the social and behavioral science programs in the BBS budget will relieve some of the funding pressures on these data bases.

Despite the proposed 10% increase in FY 1985 for the social and behavioral sciences as a whole, they will still be funded at a level that is 10% below their FY 1980 level -- even without taking inflation into account. If we calculate the effects of inflation, the proposed level for FY 1985 is 31% lower than the FY 1980 level. The share of NSF spending devoted to the social and behavioral science programs fell from 5.9% to 3.3% between 1980 and 1982 and will rise under the current request to only 3.6%, a drop of 40% in the share of the social and behavioral sciences in NSF spending. Two charts with these and other NSF budget figures are attached to this testimony.

We face a situation in which the social and behavioral sciences are now receiving budget increases that would be adequate had outlays not been slashed so deeply in 1981 and 1982. But those cuts did occur and should not be allowed to stand.

The consequences of these cuts are most apparent in the decline of single investigator projects, the seed-bed of social science research and training. The effects of this false economy are predictable and pernicious. Proposals are whittled down and stretched out to spread available funding, thereby causing delays in research and reductions in training. Scientifically ambitious investigations are jettisoned for less ambitious projects that can be accomplished less expensively. A strong research system requires not only the development and maintenance of good data bases, but also the support of established scholars and training for their successors. The support that is provided this year for the large scale data bases is a step in the right direction. It is equally important to increase support for individual investigator projects.

We realize that Congress must scrutinize every appropriation this year to see whether the nation can afford it. In answer to that question, we urge you to look at developments in basic research in the social and behavioral sciences. This is what the National Academy of Sciences/National Research Council did recently. The report of that investigation, entitled Behavioral and Social Science Research: A National Resource, describes and strongly endorses the scientific advances that have taken place in the social and behavioral sciences in recent years.

Another way to consider the question of increased support for social and behavioral science research at NSF is to examine

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some of the problems we face as a nation and the research that is conducted by social and behavioral scientists.

For example, we face a slow-down in productivity growth. Social and behavioral scientists conduct research on worker productivity and management efficiency. Research on worker productivity and quality control have led to effective techniques for linking participative decision-making and the acceptance of innovations in the workplace.

We are deregulating many branches of the economy. Hundreds of billions of dollars of investment and tens of millions of jobs are involved. Surely the investment of a few million dollars in the study of the effects of this monumental social and economic experiment is only prudent.

Newspapers report on the lag in performance of U.S. students in science and mathematics relative to students in other countries. Can we afford to curtail social and behavioral science research on memory and cognition, teaching and learning?

We face continuing problems in the courts and in the marketplace with the issue of whether wage differences between men and women are based on sex or on experience, skills, performance, or other factors. Do we wish to make decisions in these areas bereft of data and research that would enable us to compare individuals with similar experience and training and sort out the various influences on income?

The basic research in all these and many other areas has been supported by NSF in the past and we respectfully suggest that additional work is needed now.

We recognize the budget problems created for the Congress by the size of the federal deficit. However, we think that on policy grounds and on substantive grounds, the Senate Labor and Human Resources Committee should establish the goal of returning the social and behavioral science programs in the National Science Foundation to their FY 1980 levels in constant dollars. We realize that this may take time, but feel strongly that the goal must be set.

We also ask that the Committee add $5 million to the authorization for the Directorate for Biological, Behavioral, and Social Sciences and that this increase be earmarked for research in the social, behavioral, and information sciences. This amount would help to strengthen these programs that have been laboring for several years under diminished budgets.

Consortium of Social Science Associations

NATIONAL SCIENCE FOUNDATION

Funding for Selected Directorates and Programs (in million $)

	Actual FY80	Actual FY81	Actual FY82	Actual FY83	Actual FY84	Proposed FY85	%Change FY84-85	%Change FY80-85
Dir. for Mathematical and Physical Sciences (MPS)	227.0	256.5	272.9	299.7	359.5	416.7	+16	+84
Dir. for Astronomic/Atmospheric Earth & Ocean Sciences (AAEO)	218.1	236.3	240.0	276.2	330.3	373.5	+13	+71
Dir. for Engineering (ENG)	76.6	83.8	93.3	101.1	120.7	147.1	+22	+92
Dir. for Scientific, Technological & International Affairs (STIA)	36.6	36.0	40.3	44.1	40.8	46.9	+15	+28
Dir. for Biological, Behavioral & Social Sciences (BBS)	185.7	185.6	176.0	190.2	224.8	253.1	+13	+36
Social & Behavioral Science Programs in BBS	52.4	43.7	32.8	36.0	42.8	47.2	+10	-10
Social & Behavioral Science as Proportion of Research & Related Activities	5.9%	4.6%	3.3%	3.7%	3.8%	3.6%		
Science & Engineering Education	77.2	64.7	20.9	16.1	88.9	75.7	-15	-2

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NATIONAL SCIENCE FOUNDATION (cont.)

Social and Behavioral Science Research Programs in BBS (in million $):

	Actual FY80	Actual FY81	Actual FY82	Actual FY83	Actual FY84	Proposed FY85	%Change FY84-85	%Change FY80-85
Division of Behavioral and Neural Sciences (selected programs)								
Neuroscience								
Psychobiology	4.5	4.3	3.4	3.7	4.2	4.4	+5	-2
Cognitive Science								
Memory & Cognitive Proc.	2.6	2.4	2.2	2.3	2.6	2.8	+8	+8
Social & Dev. Psychology	3.3	2.6	1.5	2.1	2.6	2.7	+4	-18
(Applied Psychology - absorbed elsewhere)	1.4	1.1	--	--	--	--		
Linguistics	2.7	2.2	2.1	2.2	2.4	2.5	+4	-7
Anthropology	6.6	6.0	5.5	5.8	6.4	6.8	+6	+3
Subtotal	21.1	18.6	14.7	16.1	18.2	19.2	+5	-9
Division of Social & Economic Science								
Economics & Geography								
Economics	12.2	9.4	6.3	7.1	9.4	10.25	+9	-16
Geography	1.6	1.2	0.7	0.8	1.0	1.3	+30	-19
Social Measurement & Analysis								
Sociology	3.9	3.0	2.2	2.4	2.95	3.65	+24	-6
Meas. Meth./Data Resources	5.0	3.9	2.9	3.3	3.6	3.4	-6	-32
History/Philosophy of Science	1.5	1.1	0.9	1.1	1.35	1.6	+19	+7
Political & Policy Sciences								
Political Science	3.6	2.9	2.1	2.3	2.8	3.6	+29	--
Law & Social Sciences	0.9	0.9	1.1*	1.2	1.4	1.7	+21	+89
Regulation & Policy Analysis	2.6	2.7	0.9	0.9	1.1	1.3	+18	-50
Decision & Management Sci.			0.9	0.8	1.0	1.2	+20	N/A
Subtotal	31.3	25.1	17.6	19.9	24.6	28.0	+14	-11
TOTAL-Social & Behavioral Science Research Programs	52.4	43.7	32.3	36.0	42.8	47.2	+10	-10

*In FY 1981, this program was combined with the Law and Poli. Program of the Division of Applied Research.

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Affiliates

American Association for Public Opinion Research
American Educational Research Association
American Society of Criminology
Association for Asian Studies
Eastern Sociological Society
Economic History Association
Evaluation Network
Evaluation Research Society
History of Science Society
International Communication Association
International Studies Association
Law and Society Association
National Council on Family Relations
North Central Sociological Association
Northeastern Anthropological Association
Population Association of America
Regional Science Association
Rural Sociological Society
Social Science History Association
Society for American Archaeology
Society for the History of Technology
Society for Research in Child Development
Society for the Scientific Study of Religion
Society for Social Studies of Science
Southwestern Social Science Association

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University of Oregon
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Princeton University
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University of Washington
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Senator PELL. Thank you very much. As the chairman has said, the record will be kept open for any questions from members who are unable to be here. On behalf of the chairman, I thank all four of you for being with us this morning, and the meeting is herewith adjourned.

[Whereupon, at 11:40 a.m., the committee recessed, to reconvene at the call of the Chair.]

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